1986 HYALITE RESERVOIR - ARCTIC GRAYLING STUDY -

Prepared by OEA Research
and
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Environmental Management Associates
September 1986

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INTRODUCTION

Middle Creek Dam is located on Hyalite Creek approximately 14 miles south of Bozeman, Montana. The dam and reservoir occupy portions of sections 15, 22, and 23, T4S, R6E in Gallatin County (Figure 1). The dam is owned by the State of Montana and administered by the Montana Department of Natural Resources and Conservation (DNRC).

An investigation completed by the Corps of Engineers, Seattle District, in April 1980 revealed that the dam cannot safely pass one-half the probable maximum flood (PMF). Field inspection and preliminary hydrologic analyses indicated that the dam does not conform to inspection guidelines with respect to discharge and does not have the storage capacities needed to pass the recommended spillway design flood. There is considerable potential for loss of life and destruction of property if the dam should breach by overtopping during a large flood (HKM 1985).

A subsequent feasibility study was made by HKM Associates of Billings under contract with DNRC. The resulting report details an engineering plan and describes the financial arrangements needed to solve the safety concerns and other problems identified by the Corps of Engineers.

In summary it is proposed to excavate a large auxiliary spillway through the left abutment and raise the dam 10 feet, water level will be raised 8.2 feet (2.5 m). The existing principal spillway will be rehabilitated to provide adequate hydraulic capacity for passing the 500-year flood.

The reservoir presently contains cutthroat trout (*Salmo clarkii*), Arctic grayling (*Thymallus arcticus*), brook trout (*Salvelinus fontinalis*) and cutthroat-rainbow hybrids (Wells 1976).

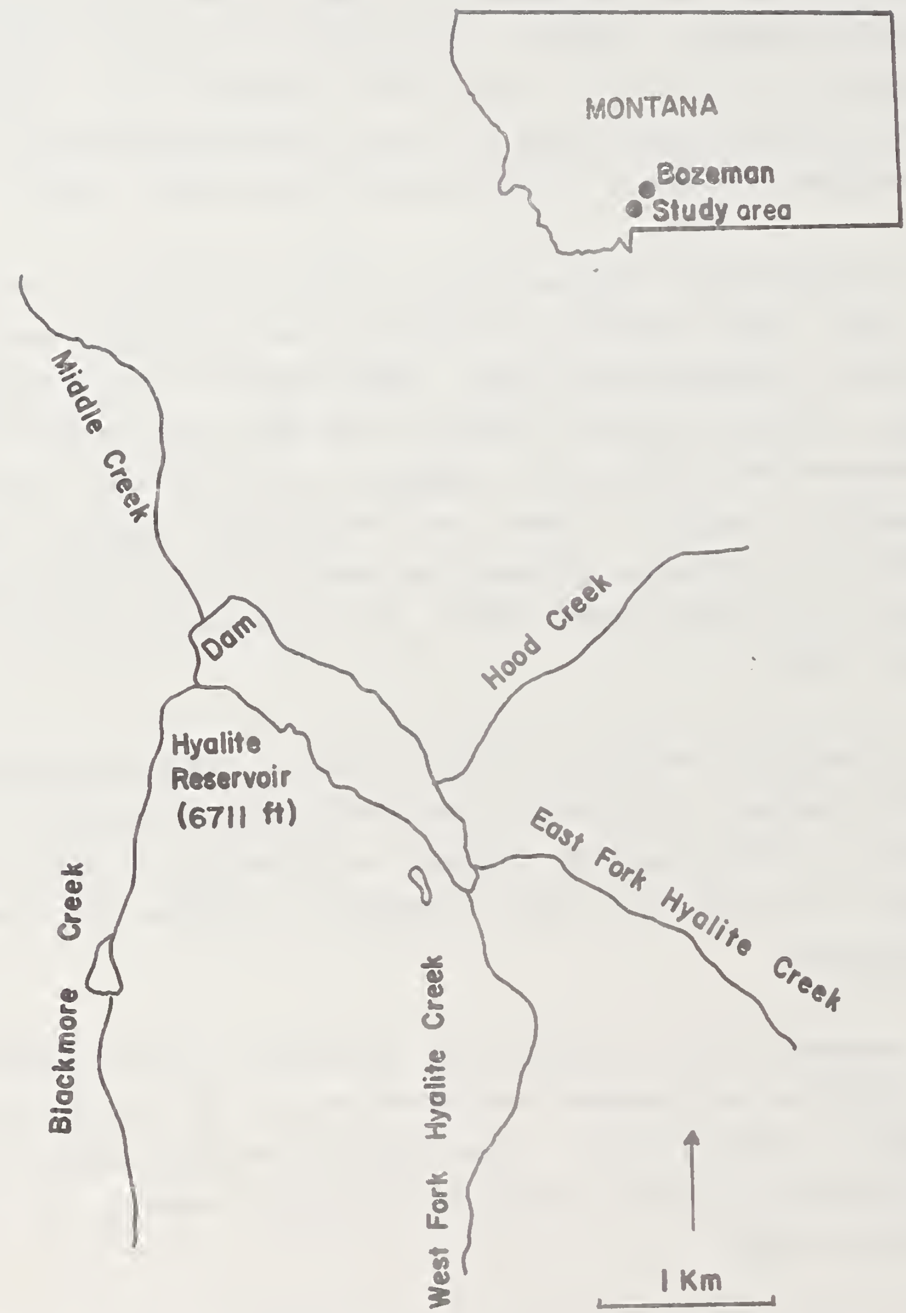


Figure 1. Map of the study area showing major inlet and outlet streams.

The grayling is considered a Class A Montana Fish of Special Concern. The Class A designation indicates limited numbers and/or limited habitats of the fish species in Montana and elsewhere in North America. Elimination of a Class A fish from Montana would be a significant loss to the gene pool of the species (MDFWP 1985).

Due to concerns expressed by various agencies regarding the effect of raising Hyalite Reservoir on grayling spawning success, DNRC initiated a study to predict the nature of this impact.

The objectives of the study were to:

- o Determine the location and extent of areas currently used for spawning by grayling.
- o Determine the percentage of the spawning areas that would be lost following construction of the proposed project.
- o Estimate the number of grayling spawning.
- o Determine the habitat characteristics important for spawning of this population (temperature, substrate particle size, water depth, water velocity).
- o Determine the areas of suitable spawning habitat not currently used that would be available following construction of the proposed project and quantify their extent.
- o Suggest mitigative measures if appropriate.

PREVIOUS FISHERIES WORK AT HYALITE RESERVOIR

Wells (1976) conducted a study of the fishery of Hyalite Reservoir during 1974 and 1975. Both forks of Hyalite Creek above the reservoir were electrofished at least twice a week from July 1 to July 23, 1975. Captured fish were weighed, measured, marked or tagged, and released. General observations of spawning activity and locations were made.

Wells found the spawning activity of both grayling and cutthroat was limited almost entirely to the West Fork where 22 adult cutthroat and 134 adult grayling were captured compared to only 3 cutthroat and 1

grayling in the East Fork. Wells attributes this to the steep gradient and lack of riffles and side channels in the East Fork. The West Fork has a low gradient for approximately 2297 feet upstream of the reservoir, many shallow riffles with good gravel, and several side channels (Wells 1976).

Grayling first appeared in the West Fork when mean daily stream temperature was 6.1°C (July 10, 1975). Highest numbers were captured on July 16, 1975 when the mean daily stream temperature was 7°C. Wells noted that the availability of suitable spawning sites did not appear to be limited. Grayling were observed spawning in shallow riffles, backwaters, and side channels of the West Fork.

Wells concluded that the grayling population is naturally reproducing and that the age structure of the population, reproductive success in 1975, and annual increment of growth suggests a healthy population that is competing successfully with the cutthroat and brook trout populations in the reservoir.

Zubik (personal communication) made incidental observations of grayling while conducting a study of cutthroat trout in the East and West Forks of Middle Creek.

No other fisheries work has been completed for the reservoir or its tributaries prior to the initiation of this study.

STUDY TEAM

Chris Hunter of OEA Research, Helena, Montana and Dave Fernet, Environmental Management Associates, Calgary, Alberta, Canada collaborated on study design, field work, and report preparation. They were assisted by OEA Research staff members. Resumes for Mssrs. Hunter and Fernet are found in Appendix A.

METHODS

LITERATURE REVIEW

The first task undertaken was a thorough review of the literature to develop background information on Arctic grayling spawning behavior and habitat preferences. The results of the literature review were then used to aid in locating and observing spawning fish. The available data were also used to compare the spawning habitat data collected during the field effort with published values.

FIELD EFFORT

The literature review indicated that water temperature was the factor which initiated the spawning run. A temperature of 7-10°C (44.6-50°F) was reported by several Montana investigators when spawning was observed. On the basis of this information visits to the East and West Forks as well as Hood and Blackmore Creeks were made every three days beginning on June 1, 1986 to take water temperatures and monitor the beginning of the spawning run. Water temperatures were recorded with a pocket thermometer that was calibrated prior to field use. Grayling were first observed in the West Fork on June 12, 1986. Noon water temperature at the mouth was 7°C (44.6°F) and the field effort began immediately. Spawning activity concluded by June 23, 1986.

Observation of Spawners

Observation of spawning pairs began on June 12 and continued through June 17, 1986. Investigators walked the West Fork from the mouth to the uppermost campground observing and counting spawning grayling (Figure 2). The East Fork was walked from the mouth to a point above the historic mine/resort site. The investigators divided their time such that each area of the stream where spawning was observed received an equal amount of observation time. Each area was visited at different times of the day as well to eliminate any bias associated with diurnal fluctuations in numbers and spawning activity. Hood Creek and

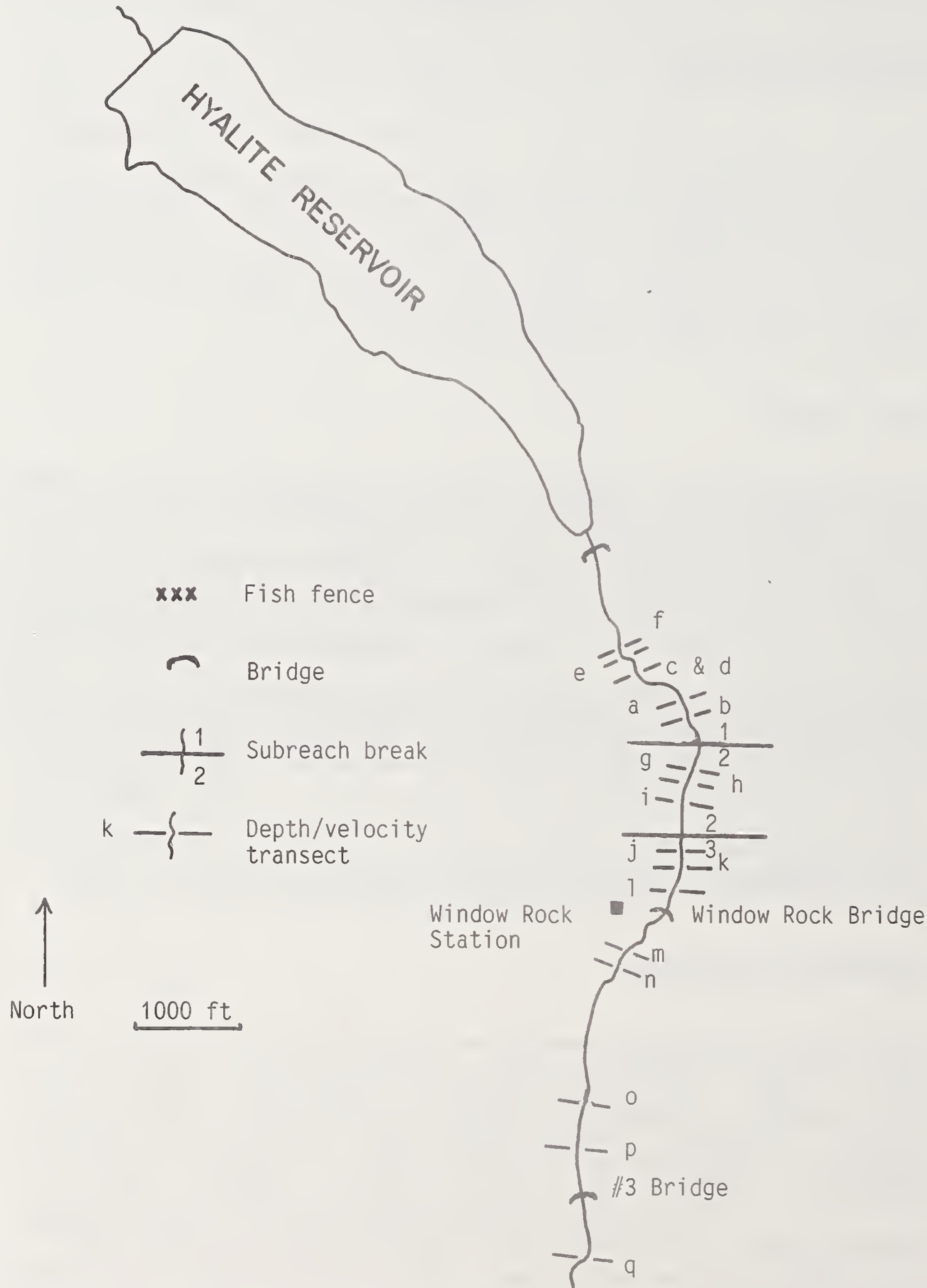


Figure 2. West Fork Hyalite Creek.

Blackmore Creek were eliminated from consideration based on very low flows, high gradients, fish passage barriers, and substrate not suitable for grayling spawning.

Water depth and velocity measurements were made at the location of each observed spawn. Velocity measurements were taken at 6/10 total water depth (mean column velocity) and within 0.15 ft of the bottom (nose velocity) with a Swoffer digital flow meter. A red flag was placed at the site. The flags were later surveyed in and located on a 1 inch = 20 feet scale map prepared by HKM Associates. The number of grayling observed in the creek was tallied June 16 during the peak of the spawning activity.

Collection of Habitat Data

The West Fork was divided into three subreaches (Figure 2). These divisions were based upon homogeneity of the habitat (gradient, substrate, channel morphology, and riparian vegetation) within each subreach.

Subreach 1 (2297 ft.) extended from the mouth of the stream to the first major logjam. This reach was low gradient and contained good habitat diversity consisting of pools, riffles, and runs. Streambank vegetation consisted principally of willows.

Subreach 2 (899 ft.) began at the first major logjam and extended to the upstream end of a steep chute section. This subreach was high gradient and consisted of a long riffle flowing through a canyon. Streambank vegetation consisted of grasses and spruce/fir forest.

Subreach 3 (3501 ft.) ran from the upstream end of the chute to the uppermost campground. This subreach was intermediate in gradient and contained some pools and side channels although it was dominated by riffle habitat. Streambank vegetation was principally willow and dry forest types.

Within each subreach several habitat transects were established perpendicular to the flow. The transects were established by stretching a 50-meter fiberglass tape from bank to bank. Transects were established in three habitat types: those deemed representative of the subreach; those where the water depth, velocity, and substrate appeared to be most suitable for grayling spawning within the subreach; and in areas of observed spawning activity (see Figure 2). Water depth and mean column velocity were measured at 1-meter intervals along these transects using a Swoffer digital flow meter. The zero point of the transects was the left bank looking downstream.

Aerial Videotaping and Mapping

An aerial videotape of the West Fork from the mouth to the uppermost campground was made for use in quantifying potential spawning areas. Prior to the videotaping, a two-person crew walked Subreach 3 of the West Fork marking areas that appeared to meet water depth, velocity, and substrate habitat criteria for successful grayling spawning. A map of the stream was made from the videotape using the Linear Measuring System (LMS) system at DNRC.

Substrate Sampling

On August 7, 1986 a two-person crew returned to the West Fork and, using the map of spawning locations, took substrate samples from fifteen spawning sites. The spawning sites were located using the map of surveyed spawning locations and triangulating with a 50-meter fiberglass tape to these points from streamside survey markers which had been placed at least every 100 feet (30.5 m). Substrate samples of 2.5-3 cm in depth were collected using a McNeil substrate sampler. The McNeil sampler is widely accepted for sampling streambed sediments (Platts et al. 1983). The samples were run through a series of sieves to determine the percent composition by size class. This analysis was performed by HKM Associates. The data sheets are found in Appendix B.

Data Analysis

Habitat data collected at Arctic grayling spawning locations were stratified into three classes: excellent, good, and marginal. The division was based upon the number and size of fish observed spawning within the area and professional judgment of the quality of the habitat. The mean column and nose velocity measurements and the substrate composition data were averaged for each class of habitat and compared to spawning habitat suitability criteria for grayling found in the literature review.

The average value for each class was then compared to depth and velocity measurements taken along the transects from the three subreaches. In this way, a general picture was developed of the availability of habitat meeting the three classes of spawning suitability criteria within the subreaches.

The number of square feet of spawning habitat (by class) currently being used was determined from the 1 inch = 20 feet map described above, using a dot grid. The percentage of this habitat that would be lost following project construction was similarly determined. A mylar map drawn from the videotape was used to determine the number of square feet of habitat meeting spawning habitat suitability criteria in areas that are not currently used and would be available following project construction. Mitigation measures were developed.

RESULTS

LITERATURE REVIEW SUMMARY

A number of the authors reviewed discussed the life history of grayling (Tack 1980; Armstrong 1982; Brown 1938; Nelson 1954; Reed 1964; de Bruyn and McCart 1974; Kratt and Smith 1980). There is general agreement that grayling migrate in early spring to spawn. Spawning occurs at temperatures ranging from 4-10°C (40-50°F). Grayling do not build redds, but the eggs are laid a few centimeters below the surface

of the substrate. Following spawning adults migrate to a summer feeding area, either a lake or stream. Incubation time of the eggs depends upon water temperature with fry hatching within 13-18 days. The fry spend their first few days in the gravel substrate, drifting into the downstream lake or river shortly thereafter.

Given this general picture of grayling life history, the following discussion provides detailed information on several important aspects of the life history.

Thermal Cues for Spawning

Wells (1976) first observed grayling in Hyalite Reservoir when the inlet temperature was 6.1°C (43°F) (July 10-16, 1975). This was one month after ice-off. He captured the greatest number of fish using electrofishing techniques when the mean daily stream temperature was 7°C (44.6°F) and mean daily surface temperature of the reservoir was 11.2°C (52°F).

Montana authors Kruse (1959), Peterman (1972), and Lund (1974) found grayling spawning runs were heaviest when stream temperatures were between 7-10°C (44.6°-50°F).

Armstrong (1982) found that a temperature of 4°C (39°F) triggers grayling to spawn in western and interior streams of Alaska. Grayling spawning takes place as early as the end of April and as late as the beginning of July.

Bishop (1971) working in Alaska observed that grayling moved into larger tributaries at ice breakup. Rising temperatures during the day seemed to stimulate spawning activities. At about noon, when temperatures of 8-10°C (46.4°-50°F) were noted, large numbers of fish would begin to move into the spawning area. Actual spawning took place at 10°C (50°F). As water temperatures fluctuated greatly during the day and night (as much as 5°C) the presence of grayling in the spawning area seemed to be related to the 8-10°C (46.4°-50°F) temperature range.

Brown (1938) discovered grayling spawning at the Agnes Lake (Montana) inlet when the water temperature was 10°C (50°F). This temperature occurred in May-June and lasted a few days to a week.

De Bruyn and McCart (1974) found that grayling spawning activity in Beaufort Sea drainages, Yukon Territory, occurred in late May-early June. This coincided with spring ice breakup.

In reviewing the work of several authors (Tyron 1947; Rawson 1950; Kruse 1959; Reed 1964; Bishop 1971; Wells 1976) Hubert et al. (1985) found that spawning had been observed to occur between 2°C and 10°C (35.6°-50°F). Most activity occurred at the upper end of the range.

Nelson (1954) studied grayling in the Centennial Valley in Montana. He observed spawning activity in Red Rock Creek from May 19 to June 6. The spawning run in Antelope Creek was more concentrated, occurring between May 23 and June 1.

Kruse (1959) working at Grebe Lake in Yellowstone National Park observed grayling spawning activity was heaviest when the range of daily average water temperatures was 40-50°F (4.4-10°C) in the tributaries. Temperatures near the surface of the lake at this time were above 45°F (7.2°C).

Peterman (1972) observed grayling moving into the Lake Agnes (Montana) inlet when the average daily stream temperature approached 2.8°C (37°F) (June 7). The peak of the run was June 11-20. Fish showed a marked diurnal fluctuation in numbers present in the inlet. Around midday, large schools were observed moving in and peak numbers were reached by late afternoon. Fish began moving downstream in the early evening. This was closely tied to the temperature of the inlet, with fish entering when the temperature rose to 4.4°C (40°F).

Tyron (1947) described grayling moving into spawning streams in late afternoon-early evening. They moved back down to the lake in the

evening. Most of the runs occurred in water close to 50°F (10°C), although some occurred with temperatures down to 40°F (4.4°C). His work was conducted at Rodger's Lake, Lake County, Montana.

Rawson (1950) found spawning to occur in late May-early June. The lake (in northern Saskatchewan) was still covered by ice and temperature of the river water at the point of spawning ranged from 7.0-9.5°C (44.6-49.1°F).

Tack (1980) found that spring migration in Alaska consisted of a pre-spawning migration to spawning areas and a post-spawning migration to feeding areas. He stated that the pre-spawning migration was probably stimulated by a general environmental stimulus, such as day length, as well as more specific stimuli such as water temperature or discharge. The migration began when water temperatures reached 1.0°C (33.8°F) and spawning began when the temperature reached 3.9°C (39°F).

Observations of grayling spawning behavior (in Alaska) were made by Reed (1964) on June 6 and May 20. Water temperatures on both dates was 42°F (5.5°C).

Lund (1974) found that grayling (in Elk Lake, Montana) began spawning runs on declining stream flows when daily lake and stream temperatures averaged 7°C.

Depth/Velocity

Tack (in Armstrong 1982) reported an average grayling spawning depth of 1.0 ft (range 0.6-2.4 ft) and average water velocity of 2.6 feet per second (fps) (range 1.1-4.8 fps).

Bishop (1971) found spawning taking place just below a riffle. Velocity was 2.5 fps, and greatest depth of the stream was 3 feet.

Brown (1938) observed a pair of grayling spawning on a swift riffle with a depth of 8-10 inches with a smooth streambottom of coarse sand.

Kruse (1959) observed spawning in several tributaries to Grebe Lake in Yellowstone National Park. He noted that water depth did not seem to be important in site selection for spawning territories by males. Some were in water so shallow that their backs and those of the females were out of water while spawning. Other territories used for spawning on the Gibbon River were between 4 and 5 feet deep. Because of the large number of fish, nearly every available location was preempted by males.

Krueger (in Hubert et al. 1985) observed a range of mean column current velocities at spawning sites from 0.35 to 1.46 meters per second (m/s) (1.15-4.79 fps).

Tack (1980) recorded mean column velocities at spawning sites ranging from 0.25 m/s (0.82 fps) to 1.0 m/s (3.28 fps).

Bendock (1979) found that grayling utilize the mainstem of the Colville River (Alaska) for spawning and appear to prefer slow-moving or slack water that is less than 0.9 m (3 ft) deep.

Substrate

Tack and Warner (in Armstong 1982) found spawning occurred most frequently in riffle areas of pea-sized gravel. Tack (1980) reported gravel particle size of 0.075-38.1 mm at spawning locations. Nelson (1954) found no eggs over sand, silt, or in pools. All eggs were found in riffles composed of gravel or rubble. Although gravel in riffle areas appears to be most commonly selected, Wojcik (in Armstrong 1982) mentioned grayling spawned primarily in slow, shallow backwater areas. Bendock (1979) reported that in some northern Alaskan lakes they spawned in the lake itself over substrates varying from large rubble to vegetated silt. Tack (1980) observed spawning among sedges over an organic bottom in a stagnant pond and Reed (1964) observed spawning over mud in a slough.

Brown (1938) found that at the Agnes Lake inlet, Montana, spawning substrate consisted of sand and fine gravel at the ratio of 3:1.

Hubert et al. (1985) in their literature review found that spawning usually occurs over gravel substrate (Rawson 1950; Nelson 1954; Bishop 1971) with transition areas between the lower end of a riffle and a pool favored. Grayling have been observed to spawn over mud-bottomed pools with vegetation (Scott and Crossman 1973 in Hubert et al. 1985) above rapids (Rawson 1950) and in shallow backwaters (Wojcik in Hubert et al. 1985) with no specific substrate selection (Tyron 1947; Reed 1964). However, Bishop (1971) and Nelson (1954) noted that spawning did not occur over pure mud, silt, or clay; only gravel, rubble, and boulder were used. Kratt and Smith (1977) found spawning over gravel 5 mm - 76 mm in diameter.

Nelson's (1954) observations in Montana's Centennial Valley yielded spawning grayling in Battle Creek, in 1951 and 1952, but no grayling fry. The bottom materials in Battle Creek were mainly detritus and peat and were probably not suitable for successful grayling reproduction. Grayling eggs were not located in bottom materials composed of sand and silt. Some eggs were found in pools, but those were always below riffles and had probably washed down into the pools. Grayling were not observed to spawn in pools. Most of Antelope Creek, another tributary to Red Rock Lake, is predominately riffles and grayling eggs were found in practically every area sampled. About 60% of Red Rock Creek is riffle area. Here the eggs were concentrated on the lower end of riffles in the transition area between riffle and pool.

Peterman (1972) observed spawning taking place over a substrate consisting of coarse, granular sand with 57% of the particles being 1.0-1.98 mm in diameter, 28% at 1.98-0.833 mm, and the remaining 15% being smaller. Spawning activity was also observed along the shoreline of the lake. All shoreline observations were made in shallow water over small gravel or coarse sand bottoms. However, visibility was limited in deeper waters and over darker mud-bottom types.

Tyron (1947) found spawning over sandy bottoms.

Kratt (1981) collected grayling eggs from pockets of sand and gravel located upstream, within, and downstream of a highway culvert. Because the stream culvert was cylindrical, substrate materials may have originated in upstream areas and been deposited by the stream current.

Rawson (1950) took most fish in spawning condition from water with gravel or rocky bottoms and in relatively quiet areas close to eddies or rapids. They were more abundant just above the rapids than below them. With no small tributaries in the study area, Rawson believed grayling spawned on rock bottoms of the main river.

Tack (1980) observed grayling spawning in unsilted, rapid run-off streams, bog streams, and lake inlets and outlets. Known spawning locations in the Tanana River (Alaska) drainage have all been in gravel bottom riffle areas. However, grayling do spawn in other substrate conditions. Grayling have been observed spawning among sedges over an organic bottom in a nearly stagnant bog. Grayling fry were collected from the stream in August, indicating reproductive success within this substrate type. Some spawning may occur in the lakes near the mouths of inlet streams (Warner in Tack 1980) but this is probably not common. Tack theorizes that grayling seek the portions of their resident systems for spawning that warm earliest in spring and remain warm during spring incubation.

Bendock (1979), in his inventory of arctic waters, found several lakes with no inlet or outlet having substrates ranging from large rubble to vegetated silt which sustained naturally reproducing populations of grayling.

Curtis (1977) in his study of grayling in Wyoming lakes and streams described the sand/fine gravel substrate of a number of inlet and outlet streams as excellent for successful grayling spawning.

Reed (1964) observed a pair of grayling spawning over a mudflat. Grayling in Alaska have been reported by fishermen to spawn over algae and sand. Laird (in Reed 1964) observed no substrate preference by grayling in Montana.

Spawning Behavior

Van Wyhe (in Armstrong 1982) observed 172 pairs of spawning grayling. Eggs were deposited at a depth of 2.5 cm (1 inch). Kratt and Smith (1977) observed that grayling eggs were buried to a depth of 2-3 cm (0.78-1.17 inches). Many eggs may be washed downstream due to this relatively shallow depth of burial (Warner in Armstrong 1976).

Bishop (1971) found that although no redd was formed by spawning grayling, eggs were covered with bottom material (sand and gravel) stirred up by the fish during spawning.

Brown (1938) observed that the sand beneath the spawning fish was agitated and stirred by caudal fins during the spawning act creating a depression of 3-4 inches deep. It was apparent that the adhesive nature of the eggs had enabled them to become completely covered with sand and deposited in the depression.

Reed (1964) also observed that grayling did not attempt to build a redd, but that tail vibrations did produce a slight depression.

Tack (1980) found spawning begins when water temperature reaches 3.0°C and usually lasts a week. Male grayling establish territories and vigorously defend them. Redds are not constructed; eggs are deposited as the posterior third of the female is forced into the gravel by the male during spawning. Eggs are adhesive prior to water hardening. Kruse (1959) noted that the size of territories established by male fish varied in size depending on the extent of the available stream-bottom in the immediate area. Territories varied from 1 ft^2 to 10 ft^2 in size. He described the defense of a territory by a male as including the opening of the mouth so that the white lining inside the jaw could

be seen. The dorsal fin was erect and the fish usually threatened the intruder with slightly rigid body movements. Similar descriptions are made by other authors reviewed.

LITERATURE REVIEW CONCLUSIONS

Hubert et al. (1985) reviewed most of the available Arctic grayling literature. Based upon the available data and the judgment of professional fisheries biologists they developed suitability index graphs for several habitat variables.

The suitability index graphs represent Hubert et al.'s (1985) best estimate of habitat suitability for spawning for various levels of each variable. The graphs were reviewed by biologists familiar with the ecology of Arctic grayling, but were not tested with field measurements. Thus, users of the graphs have been cautioned to consider the graphs as hypotheses of species response that should be verified and modified by field measurements.

Figures 3, 4, and 5 are the suitability index graphs developed for substrate and velocity.

Hubert et al. (1985) did not construct a suitability index graph for water depth spawning preferences of grayling. However, in their 1985 publication they develop category one suitability index curves for grayling spawning and egg incubation. Category one curves are curves which are based upon professional judgment and published information.

Category two (utilization) curves based upon frequency analysis of field data are fit to frequency histograms. Category three (preference curves) are utilization curves with the environmental bias removed. The introduction of an environmental bias can occur when utilization data are collected over a narrow range of available habitat types. Category four (conditional preference) curves describe habitat requirements as a function of interaction among several variables.

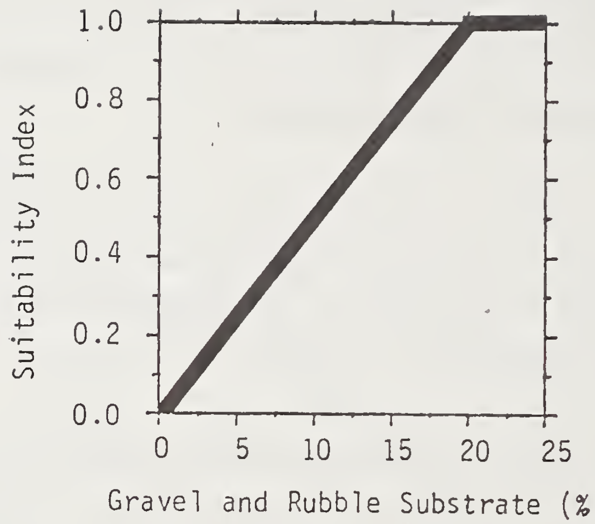


Figure 3. Percent of substrate in spawning areas composed predominantly of gravel and rubble (1.0 to 20.0 cm diameter) (Hubert et al. 1985).

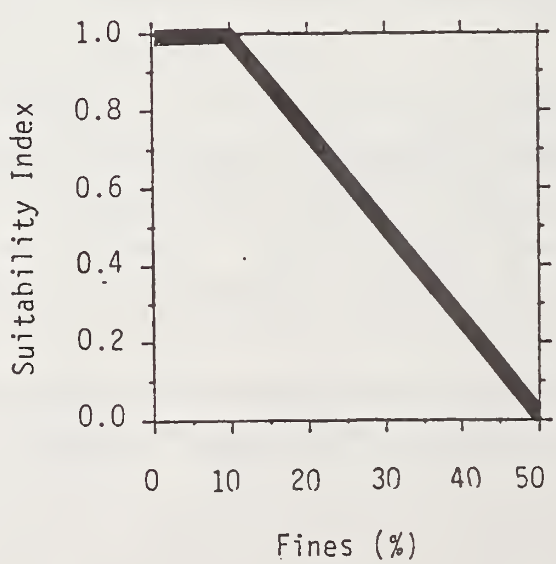


Figure 4. Percent fines (less than 3 mm diameter) in spawning areas and downstream riffle areas during spawning and embryo development period (Hubert et al. 1985).

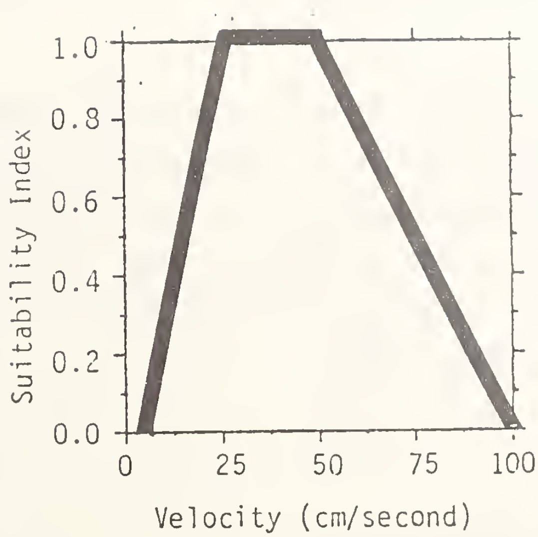


Figure 5. Average velocity (cm/s) at 0.6 the water depth over spawning areas during the spawning and embryo development period (Hubert et al. 1985).

Category one curves have not been validated by field measurements. These curves are based on the same literature review as the suitability index graphs (Hubert et al. 1985). A category one suitability index curve for grayling spawning and egg incubation water depth suitability was developed and is presented as Figure 6.

These graphs represent a "best guess" as to grayling spawning habitat requirements. The vertical axis of these graphs represents increasing suitability of the habitat variable in question. A value of 1.0 on the vertical axis is considered excellent while a zero represents poor habitat suitability.

These graphs can be used as a starting point in determining the habitat suitability of a given stream for grayling spawning. However, their value can be greatly increased if field measurments are taken to further refine these curves. The collection of the appropriate field measurements and comparison of these field data to the published curves was a significant aspect of this study.

FIELD EFFORT

Ground Observation of Spawners

Efforts to observe spawning fish were concentrated in the lowest subreach of the West Fork of Hyalite Creek. Based upon the initial reconnaissance of the streams, Hood and Blackmore creeks were eliminated from consideration due to low flows, high gradients, fish passage problems, and lack of suitable substrate. Spawning fish were not observed in the East Fork or in the remaining two subreaches of the West Fork, hence the decision to concentrate observation efforts in the first subreach of the West Fork. Figure 7 shows the surveyed locations of observed spawning activity in this subreach. Several grayling were observed up to 50 meters upstream of the spawning activity locations shown on the map; however, these fish were not observed spawning.

x	y
0.0	0.0
0.4	0.0
1.0	1.0
100.0	1.0

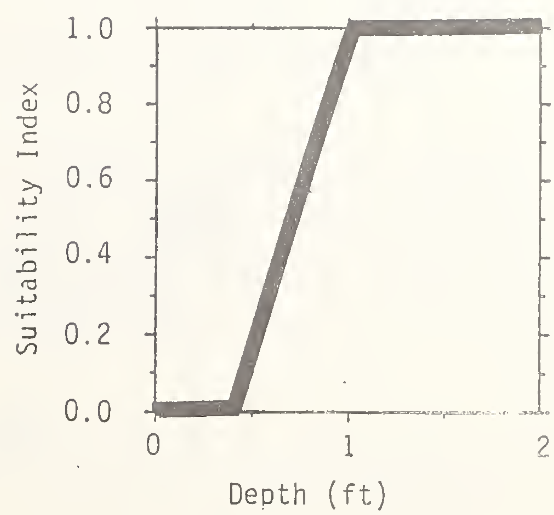


Figure 6. Category one SI curves for Arctic grayling spawning and egg incubation water depth suitability (Hubert et al. 1985).

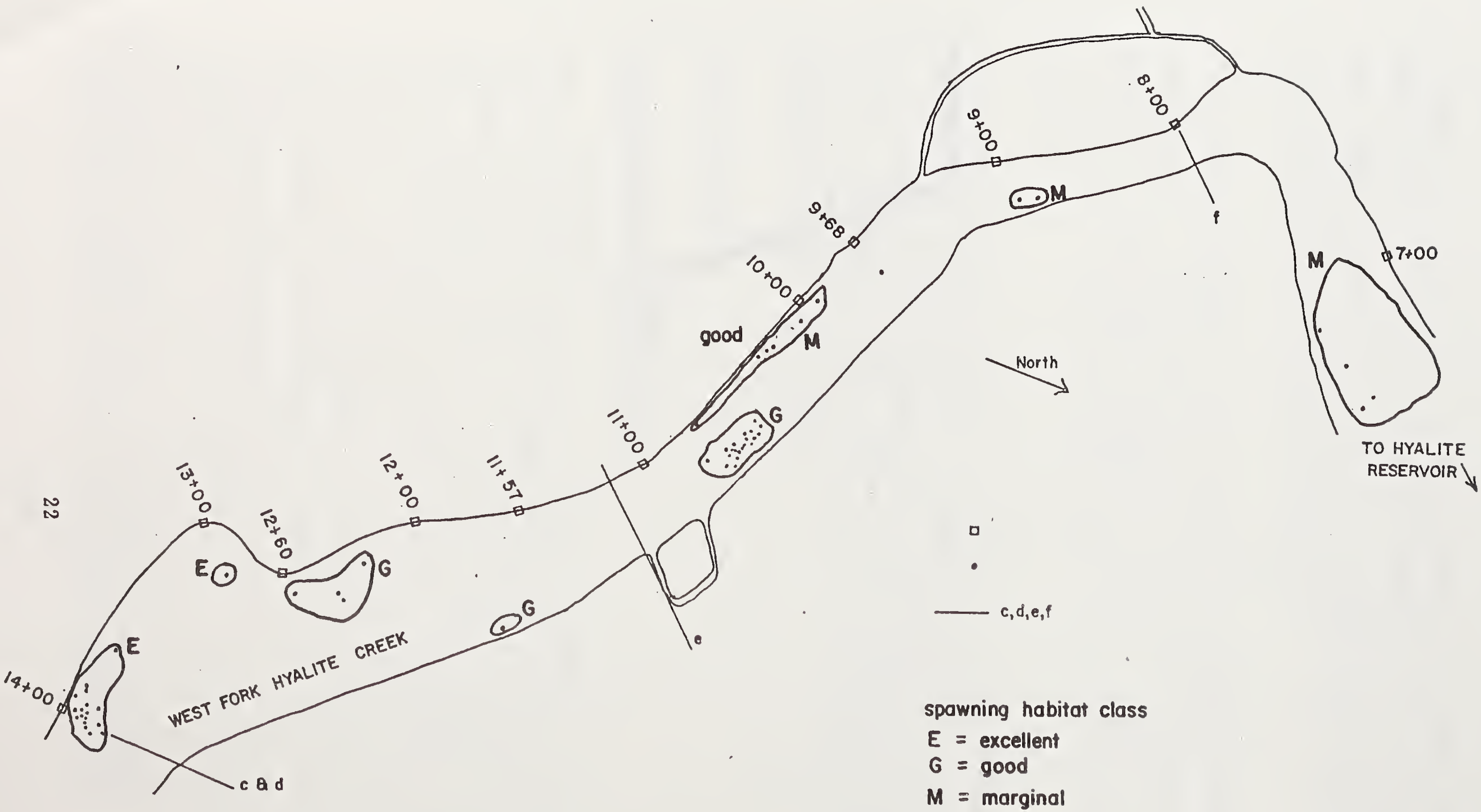


Figure 7. Locations of observed spawning and depth/velocity transects in subreach 1 of West Fork Hyalite Creek. Spawning areas identified by class.

Grayling made daily migrations from the reservoir into the stream for spawning. The migrations began about midday when temperatures reached 7-8°C (44.6-46.5°F). The males moved upstream first and established territories. The territories varied in size, apparently in response to the availability of habitat. Spawning activity was concentrated in two areas. The most important of these was near the 14+00 survey marker (Figure 7). The 14+00 survey marker is located at the point 1400 feet upstream of the bridge at the mouth of the West Fork. The depth, velocity and substrate here were excellent and the male fish were larger in this area than in other areas. The area was densely populated with fish and territory sizes were small (2 x 3 ft).

The second area of concentration was between markers 11+00 and 10+00. Here the habitat was considered good by the investigators. Territories were again small compared to those described in the literature.

The greatest number of male fish with established territories was found downstream of survey marker 7+00. In this area the spawning habitat was classified as marginal, male fish smaller, territories larger, and few successful spawns observed. Full pool elevation was in the vicinity of the 6+00 survey marker.

Male fish held their territories waiting for female fish to enter them. If another male fish entered the territory the resident male displayed one or more of several agonistic behaviors including raising the dorsal fin while moving toward the intruder and opening the mouth to display the white of the inner mouth. The fish were quite dark and the contrast with the white inside of the mouth was striking. If the behavioral displays did not scare off the intruder, he was chased from the territory.

The spawning act occurred as described by several authors with the male fish curling his dorsal fin over the back of the female. We observed that as the female released eggs and the male released milt, the male attempted to force the female into the substrate with his dorsal fin. The effectiveness of this attempt varied; sometimes the female

deposited the eggs into the substrate, but often they were deposited at the surface of the substrate.

On June 16, 152 grayling were counted in subreach 1. It is not possible to estimate the total number of spawning grayling based on this count.

Habitat Data Collection and Substrate Sampling

Classification

Following the completion of an observed spawning act the depth and mean column and nose velocities were measured at that point. The resulting data were stratified according to whether the habitat appeared to be excellent, good, or marginal. The data were then averaged and standard deviations computed, all observed values are presented in Appendix C. Table 1 presents the average values by class. The judgement regarding the suitability of the habitat was based upon information obtained in the literature review, the number and size of fish observed spawning and professional judgment based on experience with similar studies of grayling.

Table 1. Average values by class.

Habitat Class	Mean Depth	Standard Deviation	Mean Column Velocity (6/10)	Standard Deviation	Nose Velocity (0.15 ft)	Standard Deviation
Excellent	1.6 ft	0.27	63 cm/s	12.6	46 cm/s	11.2
Good	1.2 ft	0.28	109 cm/s	20.3	55 cm/s	15.6
Marginal	0.7 ft	0.19	94 cm/s	13.7	63 cm/s	9.5

Figure 8 displays the data points representing the percent fines (less than 3 mm in diameter) found in substrate samples collected from areas where spawning was observed. These points have been plotted over Figure 4 to show how data collected in this study compares with the habitat suitablity index curves prepared by Hubert et al. (1985).

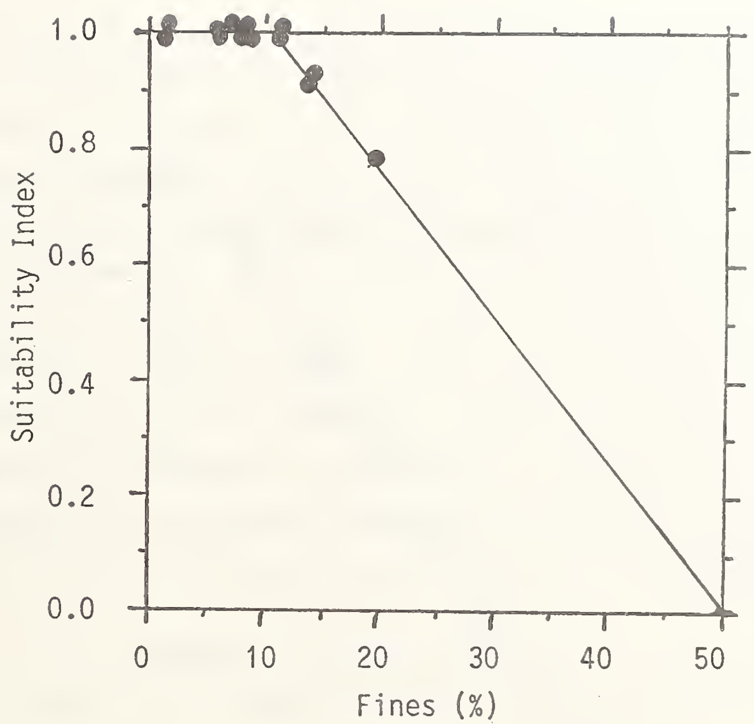


Figure 8. The data points representing fines (less than 3 mm in diameter) found in substrate samples collected from areas where spawning was observed, 1986 data.

Figures 9 and 10 were prepared in the same way and display the data points for mean column velocity (Figure 5) and depth (Figure 6) at observed spawning sites respectively.

These graphs and Table 1 show that virtually all of the spawning occurred in areas having substrate habitat suitability of 1.0. This is true regardless of whether the spawning site was classified as excellent, good, or marginal.

The plotted points and graph of mean column velocity/habitat suitability shows that most of the spawning occurred in areas where mean column velocity was substantially higher than represented on the Hubert et al. graph as optimal for spawning. It is thought that this is because the fish are keying on velocities near the bottom when selecting a spawning site, thus nose velocity is a much more meaningful measure of habitat suitability than mean column velocity. This is borne out by the mean values by class for mean column and nose velocities. The mean values of mean column velocity for areas classified as good is higher than for those classified as marginal. However, the opposite is true when the mean nose velocity for good and marginal habitats are compared. Thus nose velocity appears to be the preferred measure of habitat suitability.

The plotted points of water depth/habitat suitability shows excellent correlation with the graph prepared by Hubert et al. (1985).

Transect Measurements

As described under Methods, the West Fork was divided into subreaches and water depth and velocity measurements were taken at several transects within each subreach. These transects are represented in Figures 11, 12, 13, 14, 15 and 16. The vertical lines denote the points where the measurements were taken. The mean column velocity in fps at that point is shown at the top of the vertical. The number in the panel between the verticals is the average of the velocity measurements at the two verticals which define that panel. The panel number is found

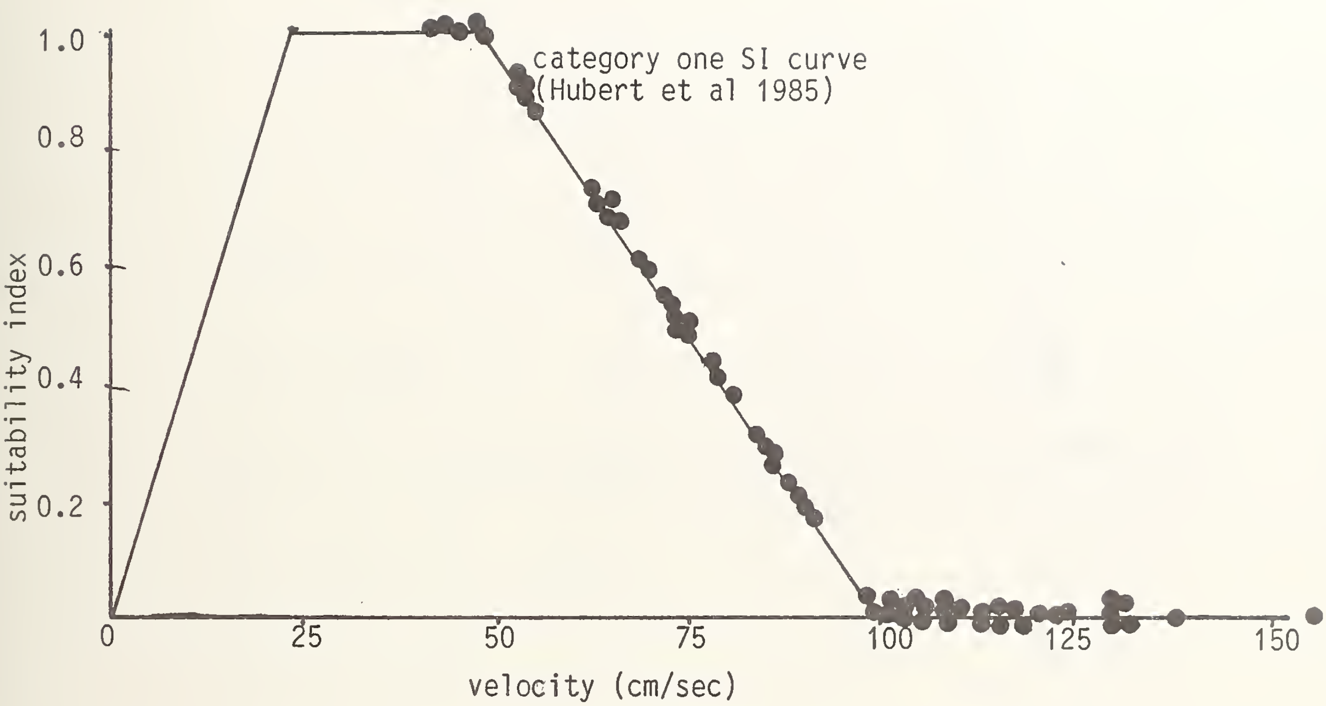


Figure 9. Average velocity (cm/sec) at 0.6 the water depth over spawning areas during the spawning and embryo development period. Plotted with category one suitability index curve.

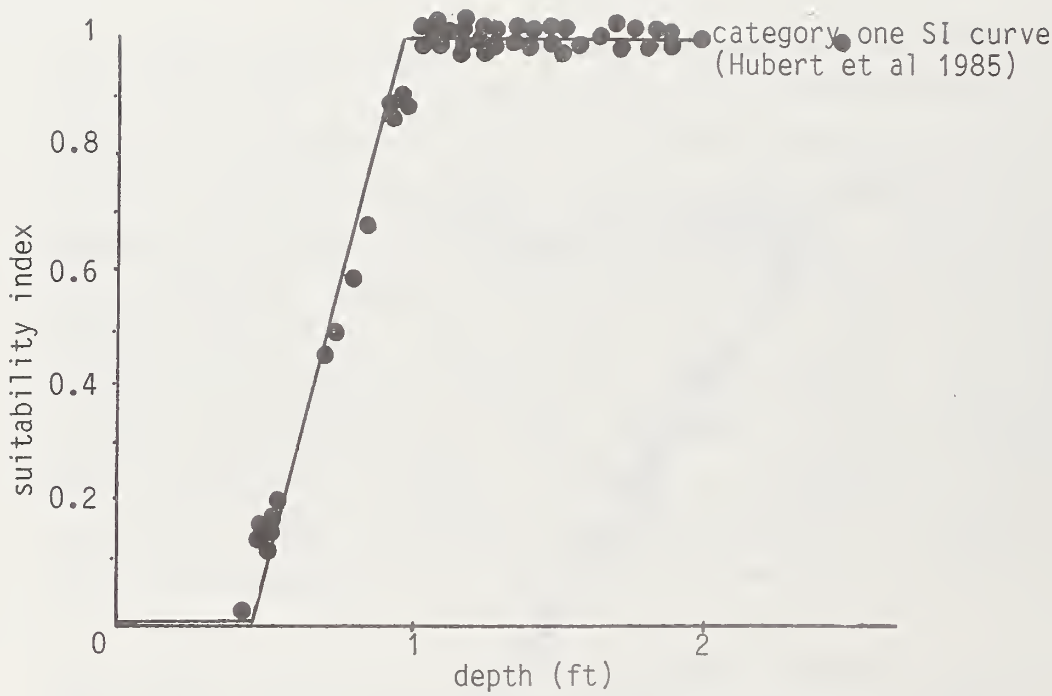


Figure 10. Arctic grayling spawning and egg incubation water depth suitability. Plotted with category one suitability index curve.

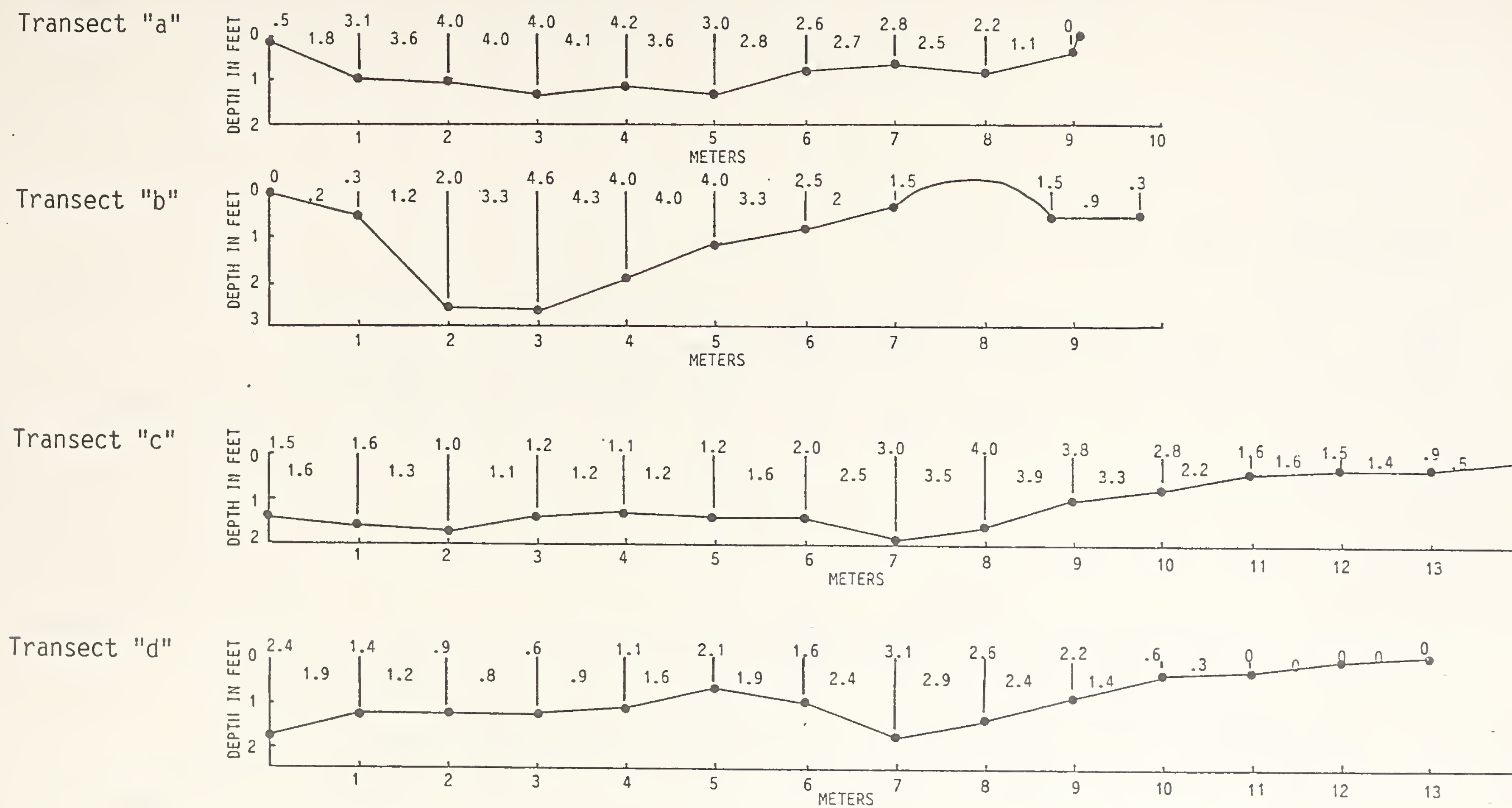
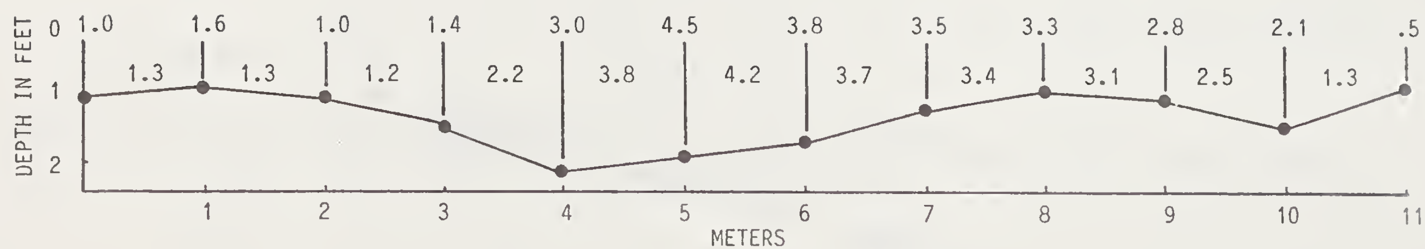


Figure 11. Water depth/velocity measurements for transects "a", "b", "c", and "d".

Transect "e"



Transect "f"

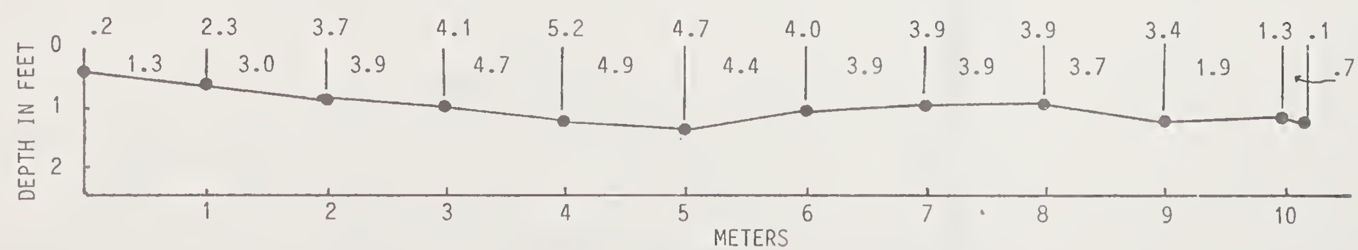


Figure 12. Water depth/velocity measurements for transects "e" and "f".

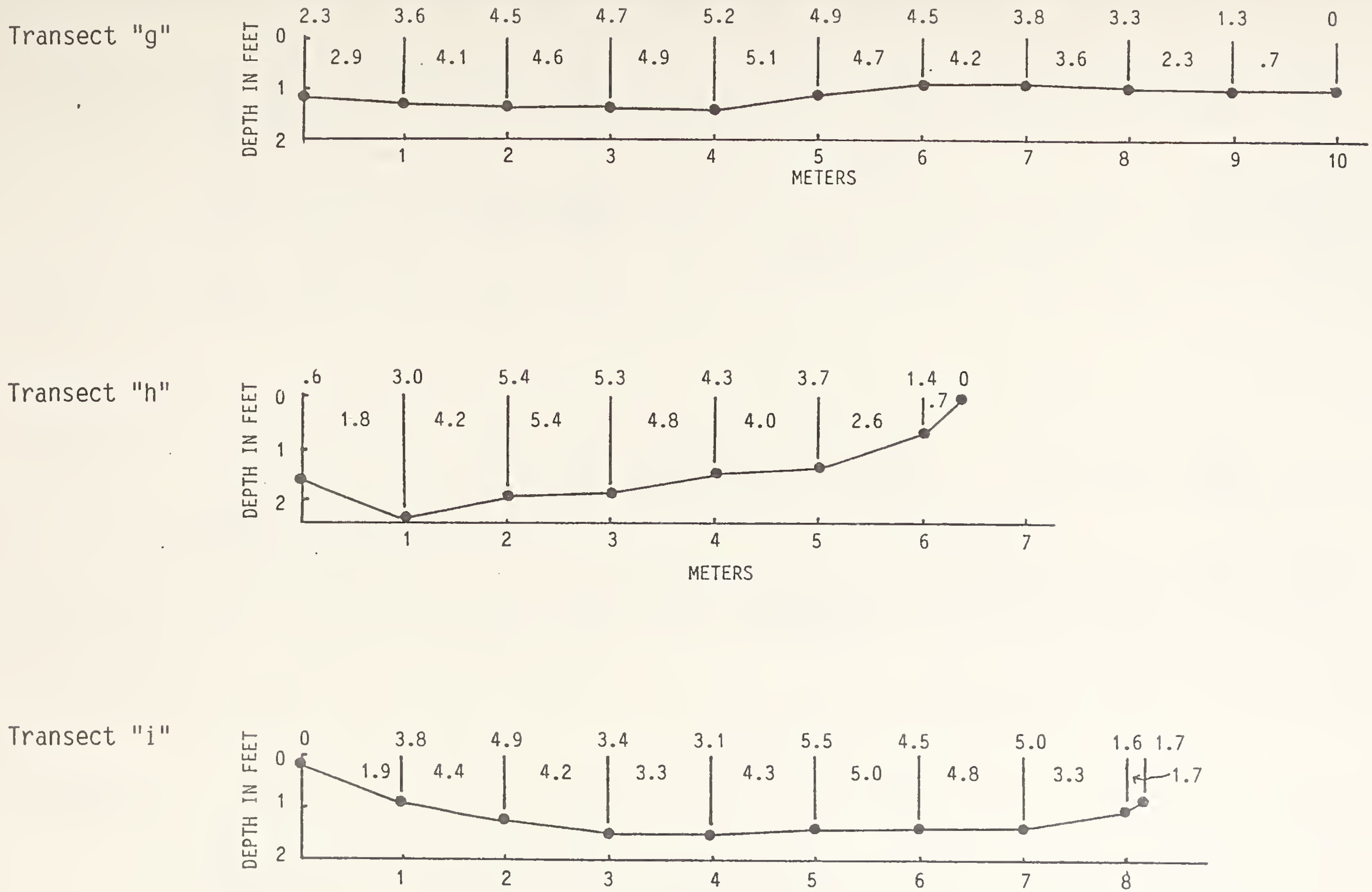


Figure 13. Water depth/velocity measurements for transects "g", "h", and "i".

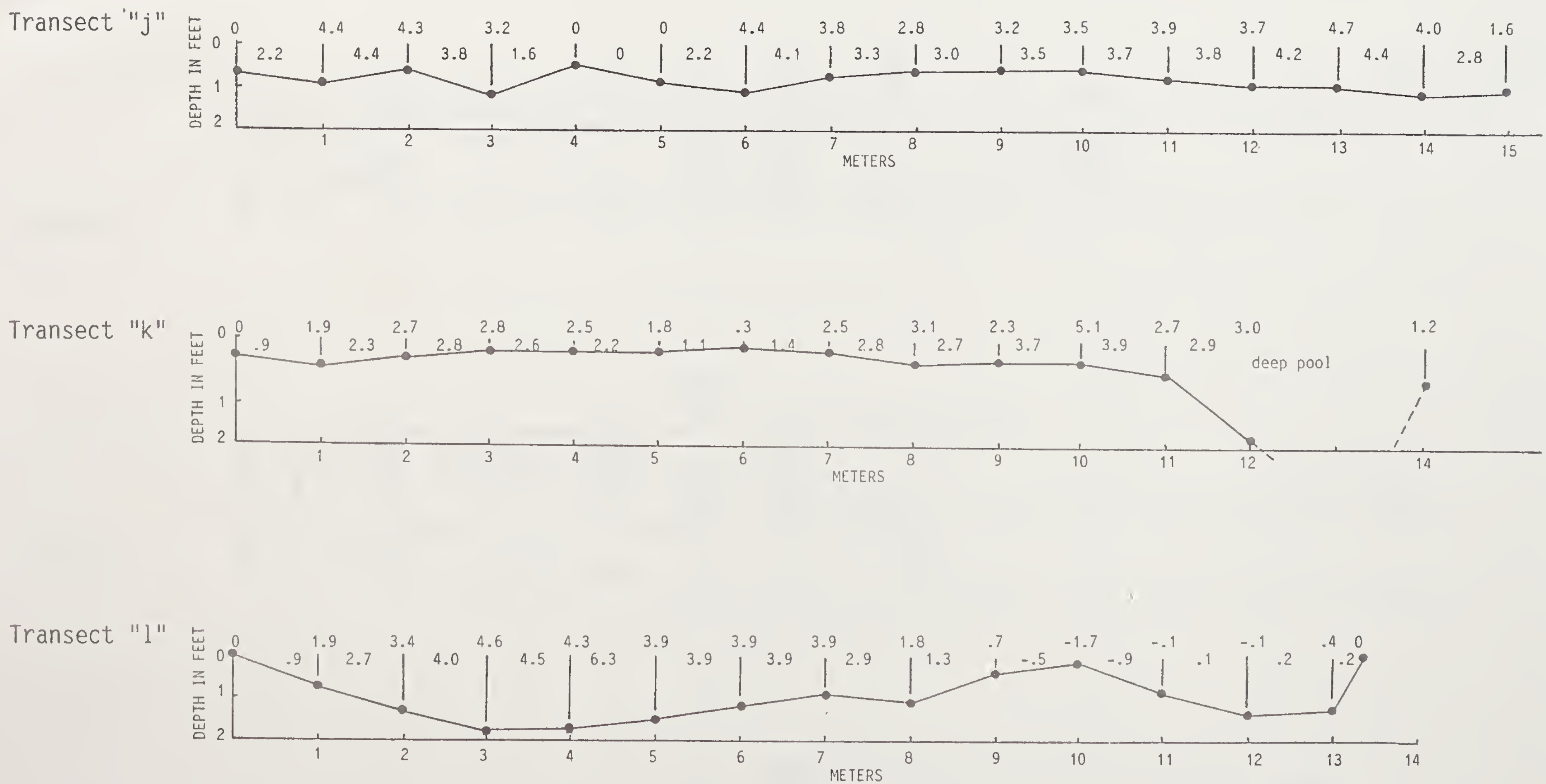


Figure 14. Water depth/velocity measurements for transects "j", "k", and "l".

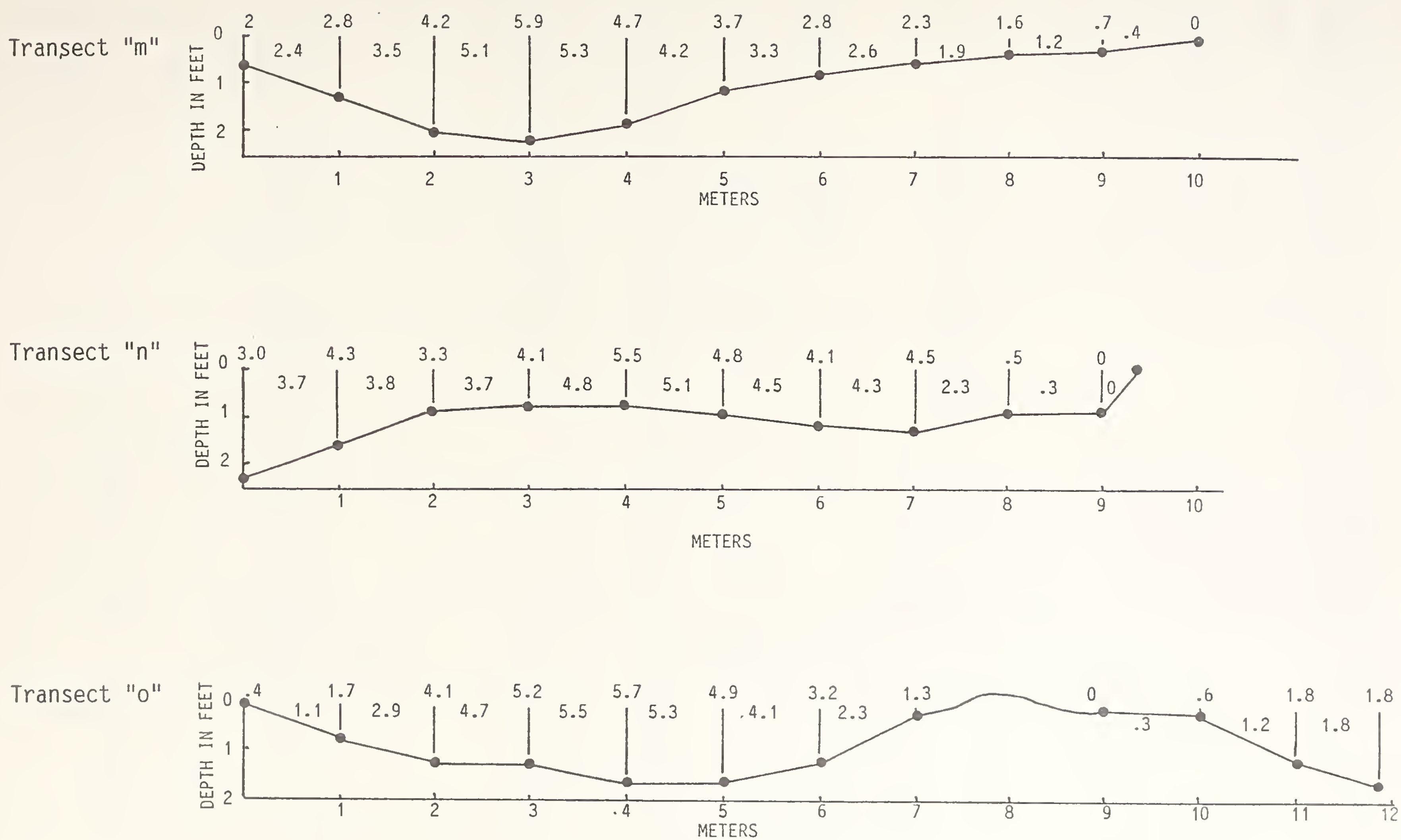


Figure 15. Water depth/velocity measurements for transects "m", "n", and "o".

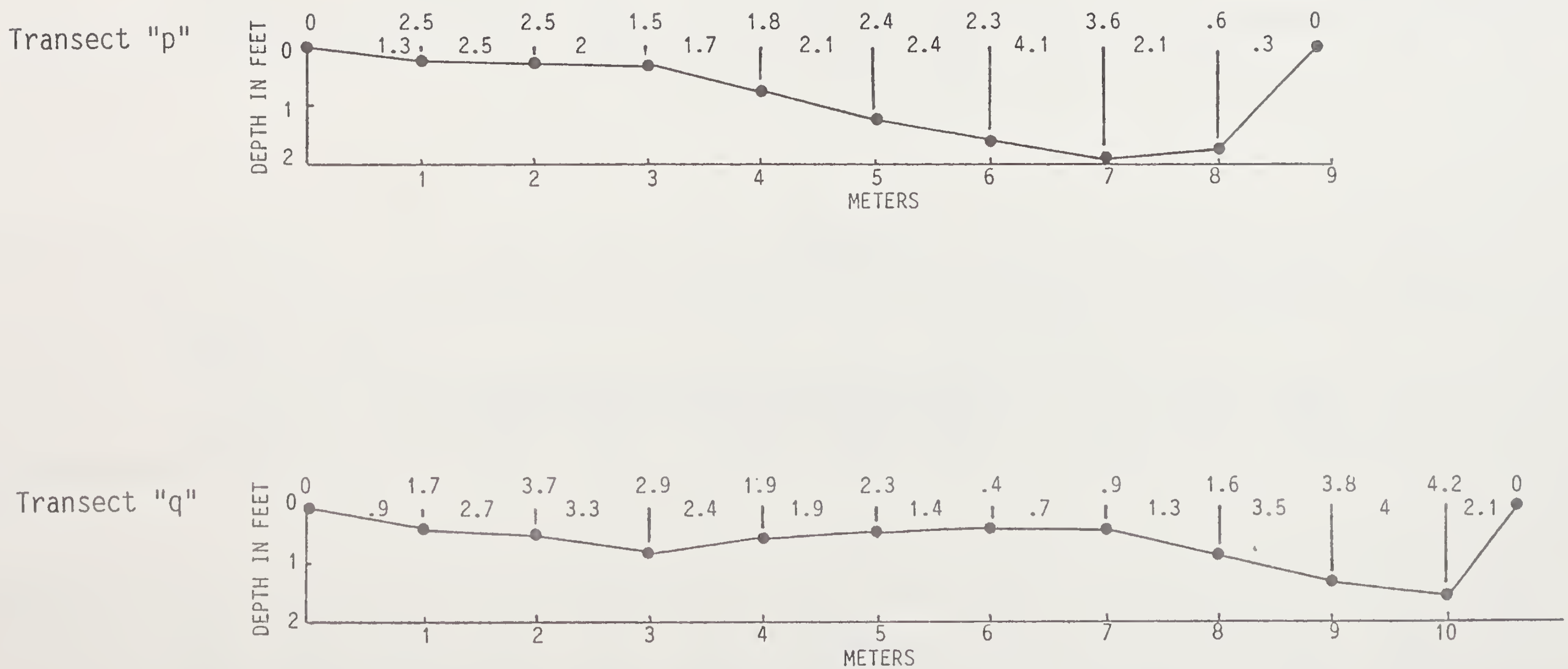


Figure 16. Water depth/velocity measurements for transects "p" and "q".

on the horizontal axis at the right hand edge of the panel. The stream bottom is depicted by the line connecting the lower ends of the vertical lines.

The depths and velocities for the panels at each transect were compared to the mean values for excellent, good, and marginal habitat. This was done to develop a general idea of habitat suitability for grayling spawning within each subreach. The results of this comparison are presented in Table 2.

Table 2. Results of comparison of depth/velocity transects with observed spawning habitat preferences.

		Percentage of Transect Containing Habitat Suitable for Spawning		
Subreach	Transect	Excellent	Good	Marginal
1	a	-	-	11%
	b	-	5%	5%
	c-d*	43%	7%	-
	e*	9%	27%	-
	f	-	-	10%
2	g	-	-	8%
	h	-	-	10%
	i	-	-	-
3	j*	-	-	20%
	k	-	-	-
	l*	-	-	15%
	m*	-	-	15%
	n	-	-	8%
	o*	12%	12%	6%
	p*	-	20%	-
	q	-	-	8%

* Transects selected because spawning observed here or habitat appeared suitable. These are not representative of the subreach.

Transect "a": Located at Forest Service pin #13 which is approximately 30 m downstream of the logjam and the upstream end of the reach. None of the nine panels contain excellent habitat; one panel (6) has marginal habitat.

Transect "b": Located in a straight portion of the subreach where grayling were observed; no spawning was observed. This is upstream of the most upstream spawning observed. There is no excellent habitat along this transect. Approximately 10% of the transect covers habitat that would be good to marginal (portions of panels 2 and 6).

Transects "c" and "d": Both were taken at the 14+00 survey stake. Transect "c" was taken June 15 and June 23. The difference in the transects reflects the change in the flow régime during this time. These transects bisect the area where the greatest amount of spawning activity was observed. Six of the fourteen panels (1-6) of transect "c" have excellent spawning habitat and panel 7 has good to marginal habitat.

Transects "e" and "f": Transect "e" was located just upstream of the 11+00 survey stake and transect "f" in the vicinity of the 8+00 survey stake. Nine percent of "e" covers excellent habitat while 27% of the area covered is considered good spawning habitat. Approximately 10% of transect "f" covers habitat that would be classified marginal.

These transects show that although the spawning activity observed was limited to subreach 1, even within this reach suitable spawning habitat is not abundant.

Transects "g", "h", and "i": All were located in subreach 2. This subreach is a narrow, straight, high gradient chute that extends several hundred meters upstream of the first major logjam. Transects "g" and "h" cover a cell or less of marginal spawning habitat, while there is nothing even marginally suitable at transect "i". This reach has no value as a grayling spawning area. However, it does not present a passage barrier for fish headed upstream.

Transects "j", "k", and "l": Located in subreach 3 between the upper end of the chute and the Window Rock Bridge. Transect "j" is not typical of this area, rather it is representative of the best spawning

habitat in this subreach. It appears that about 20% of this transect covers areas with depth and velocity that would be marginally suitable for grayling spawning (panels 4, 6, and 15). However, there is very little pool/riffle structure which is important to successful spawning and rearing.

Transect "k" contained no suitable spawning habitat; transect "l" approximately 15% marginal habitat. Transect "l", like "j", was not representative of the subreach, but rather of the best the subreach had to offer. Portions of panels 2, 8, and 9 appear to contain good to marginal habitat.

<u>Transects "m", "n", "o", and "p"</u>: These transects were established between the Window Rock Bridge and bridge #3. Transect "m" was established to reflect better grayling spawning conditions than generally occurred in the reach. Approximately 10-15% of the area covered is categorized as marginal habitat (portions of panels 1, 2, and 7). Transect "n" is indicative of the general conditions within the reach; less than 10% of the area covered is considered to be marginally suitable (cell 8). The three transects "j", "l", and "m" (selected to show the best conditions available within the reach) are all in similar locations. In each case the suitable habitat is found at the edge of a gravel bar where the current has sorted the substrate by size. In these few instances, the depth is sufficient and velocity low enough in the area of suitable substrate that these areas could be used for spawning.

Transect "o" was established primarily to evaluate the suitability of a side channel located several hundred meters downstream of bridge #3. This side channel is represented by panels 11 and 12 which contain the best depth and velocity values found above subreach 1. Panels 2 and 7 also contain good to marginal spawning habitat.

Transect "p" was located at a gravel bar/pool area where substrate, depth, and velocity appeared to be suitable for spawning. Cells 5 and 6 contained habitat, about 20% of the total transect, that would be considered good spawning habitat.

Transect "q" was the final transect and considered indicative of the area between bridge #3 and the uppermost Forest Service campground. Less than 10% of the area covered by this transect contains marginally suitable spawning habitat. This is found in panels 8 and 11.

Having developed a general idea of the availability of habitat suitable for spawning by reach, we wanted to attempt to better quantify the actual square footage of spawning habitat. This was a relatively simple task for subreach 1 where the observed spawning locations had been surveyed and mapped. A line was drawn around each of the spawning areas (Figure 7) and the number of square feet of that particular class of habitat was determined using a dot grid. The number of square feet of spawning area currently used in subreach 1 by cells was 348 ft^2 excellent, 736 ft^2 good, and 2748 ft^2 marginal.

Computing the number of square feet of spawning habitat upstream of subreach 1 was more difficult. A team of two biologists walked the stream from the lower end of subreach 2 to the top of subreach 3, locating points where it appeared that the substrate, depth, and velocity were suitable for spawning. At each point water depth and mean column velocity were measured, the square footage was estimated, and an "X" (3 ft x 3 ft) was placed on the streambank nearest the location. Nine such locations were found. These are noted on the map found in Appendix D; depth and mean column velocity for each is presented in Table 3.

Table 3. Depth and mean column velocity for points determined suitable for spawning.

Point	Depth	Mean Column Velocity		Area
1	1.6 ft	2.3 fps	70.1 cm/s	6 ft^2
2	1.3 ft	1.25 fps	38.1 cm/s	10 ft^2
3	1.25 ft	2.6 fps	79.2 cm/s	4-6 ft^2
4	0.45 ft	1.5 fps	45.7 cm/s	4-6 ft^2
5	0.6 ft	2.1 fps	64.0 cm/s	12 ft^2
6	0.8 ft	1.9 fps	57.9 cm/s	6 ft^2
7	0.8 ft	1.8 fps	54.9 cm/s	15 ft^2
8	0.8 ft	1.7 fps	51.8 cm/s	16 ft^2
9	0.5 ft	1.9 fps	57.9 cm/s	6 ft^2

Aerial Videotaping and Mapping

When site marking was completed, a helicopter was used to make an aerial videotape of the stream from the mouth to the top of subreach 3. The videotape was then used to develop a map of the stream showing potential spawning locations and their relationship to important stream features such as pool:riffle sequences. This was accomplished by tracing the image of the stream and important features (logjams, riffles, pools) that were projected onto mylar by the Linear Measuring System at DNRC.

It was then possible to locate on the videotape and mylar map areas similar to the nine marked sites. The areas of such sites were estimated using the dot grid and combined with the areas measured at the nine previously described sites. In this way a quantitative estimate of habitat suitable for spawning in subreach 3 was generated. Those areas which were selected from the videotape and not visited on the ground were placed in the marginal habitat category since depth and velocity data were not available for them.

A total of 245 ft^2 of suitable Arctic grayling spawning habitat was found in subreach 3. The number of square feet of spawning habitat, by class was 12 ft^2 (1.11 m^2) of excellent habitat, 16 ft^2 (1.49 m^2) of good habitat, and 217 ft^2 (20.16 m^2) of marginal habitat.

The review of the videotape revealed a great deal about the structure of the stream. Subreaches 1 and 2 were in fact fairly homogeneous and had been accurately characterized during the field effort. Subreach 3 was less homogeneous than our field observations had indicated. There was a stretch below Window Rock Bridge that, like subreach 2, was a long high gradient riffle. Between Window Rock Bridge and bridge #3 the channel was much more complex. A series of logjams, gravel bars, and side channels provide a diversity of habitat in this subreach that was not observed elsewhere above subreach 1. Most of the areas identified by the field crew and on the videotape as being potentially suitable for grayling spawning were located in this portion of the subreach. A large scale map of this area can be found in Appendix D.

A final data analysis was done to determine the amount of habitat currently used that would be inundated by the proposed project. The proposed full pool elevation was compared to the elevations of observed spawning sites. All of the observed spawning sites would be lost if the project (as proposed) is constructed. Suitable habitat found in subreach 3 would not be affected by the proposed project.

DISCUSSION

The literature review and the spawning site depth, velocity, and substrate data collected during the course of this study show that preferred grayling spawning habitat unlike that of other salmonids, is slow-moving water of 1-2 feet (0.3-0.6 m) in depth with a gravel substrate. This spawning habitat must be associated with pools, backwaters, and side channels to provide resting habitat for adult spawners. This habitat is limited in the West Fork of Hyalite Creek. Even in Subreach 1 there is little of this habitat available, although apparently enough to sustain the Hyalite Reservoir Arctic grayling population. This habitat has great value due to short supply. There is more of this habitat in the West Fork than in any of the other tributaries to Hyalite Reservoir.

The field data collected also showed that while adequate substrate was available, areas having the necessary depth and velocity requirements for excellent spawning conditions were limited. This is indicated by the fact that substrate samples collected from all classes of spawning habitat had very similar composition (Appendix B).

The field data indicate that nose velocity is a much better indicator of habitat suitablity for spawning than is mean column velocity. This is discussed under Results.

The general and quantitative analyses of the availability of spawning habitat in the West Fork demonstrate that over 90% of the available stream spawning habitat and nearly 100% of the identified stream spawning habitat classed as excellent will be lost due to the construction of

the proposed project. No attempt was made to assess spawning activity along the lakeshore although this has been documented by other authors.

This loss would seriously affect the grayling population of Hyalite Reservoir unless mitigative measures are taken. If the project is to be constructed as proposed, mitigative measures must be incorporated into the project plan. To develop a mitigation plan several questions must be answered:

- How much of each class of habitat does the population require in order to maintain its current condition?

- Would the habitat in subreach 3 be used if the project eliminated the spawning areas currently used?

- Can anything be done to enhance habitat in subreach 3 to mitigate for the loss of habitat in subreach 1?

It is assumed that the habitat available in subreach 1 is adequate to maintain the population in its current condition. This conclusion follows because if the habitat was limiting the population fish would have been expected upstream of subreach 1. Since there are no physical barriers to fish passage above subreach 1 it appears that fish are not going upstream because there is sufficient spawning habitat within the first subreach. Suitable spawning areas were observed in subreach 3.

If the spawning areas in subreach 1 were inundated by the project, it is assumed that the grayling would move upstream through subreach 2 and into subreach 3 seeking suitable spawning sites. This assumption is based upon several reasons: 1) grayling have been observed to move into new areas to spawn when their former spawning sites were eliminated (observation made by Dave Fernet); 2) there are no physical barriers to their movements; and 3) previous investigators (Wells 1976; Zubik, personal communication) have observed grayling in subreach 3.

The single largest factor limiting the availability of spawning habitat in subreaches 2 and 3 is stream gradient. Water velocity, stream channel morphology, and substrate size are all, to a large extent, functions of stream gradient given that other factors such as water volume, sediment production, and streambank stability are equal. The only area of significant size in subreach 1 that meets criteria for providing excellent spawning habitat is formed by a logjam creating a pool situation. Within the pool, velocities are reduced, water depth is greater, smaller substrate dominates, and resting habitat is provided for adults.

There are several side channels in the first quarter-mile downstream of bridge #3 in subreach 3. Transect "o" passed through one of these sites. It had the best habitat of the transects in subreach 3. It should be possible to enhance these existing side channels and pool areas for grayling spawning. In this way excellent spawning habitat equal (in area) to or greater than that which currently exists in subreach 1 could be created, thus mitigating the loss of habitat in subreach 1.

Enhancement of existing side channels and pool areas could be accomplished utilizing natural materials (trees, rock-filled gabions). The intent should be to create habitat having the same habitat characteristics as those areas where spawning was observed that were classified as excellent. An important consideration will be to insure that the habitat is covered with flowing water during the time of egg incubation.

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- APPENDIX A -

Resumes

CHRISTOPHER J. HUNTER

GENERAL MANAGER
AQUATIC BIOLOGIST

Education:

University of Montana, Missoula, M.A. Zoology/Limnology, 1974
University of California, Santa Barbara, B.A. Biology, 1972

Experience:

1981 - Present: General Manager/Limnologist, OEA RESEARCH

Mr. Hunter's duties include general management of all operations, personnel assignment, scheduling, study plan development, fiscal management, and contract negotiations. He also provides direct technical input on limnological and other water resource related studies, as needed.

- Silver Bow Creek CERCLA Site Algae and Macroinvertebrate Remedial Investigations. Reviewed algal and water quality data to determine if algae play a role in trace metal transport in the river system. Summarized existing macroinvertebrate data, evaluated degradation of the river in light of this data and recommended data collection to monitor success of remedial actions.

- Boise National Forest Aquatic/Riparian Habitat Survey. Project manager and aquatic team leader for an intensive survey of aquatic and riparian habitat for over 250 miles of stream in the Salmon River drainage of central Idaho.

- Swan River Drainage Micro Hydropower. Collected and reviewed fisheries, flow, and habitat information for four proposed micro hydropower sites. Prepared a report analyzing water demands of the projects, flow duration curves, spawning potential of the streams and recommending which creeks were suitable sites.

- Hard Rock Mine Permits. Conducted complete baseline fish, fisheries habitat, macro invertebrate and periphyton inventory for three proposed gold mines in the Black Hills, South Dakota. Studies included electrofishing. The final reports were used in the applications for permits to mine.

- Prickly Pear Abandoned Mine Land Study. Conducted an investigation of impacts of abandoned mine drainage on aquatic biota in the Prickly Pear Creek drainage.

- Crow Tribe Abandoned Mine Land Study. Assessed the effect of proposed mine reclamation strategies on aquatic systems.

- Hauser Lake Limnology Study. Conducted a complete limnological investigation of Hauser Lake including quantitative zoo- and phytoplankton, primary productivity, water quality. Prepared report for a Federal Energy Regulatory Agency hydropower permit application.

- Roundup-Ivanhoe and Stillwater Valley Studies. Provided overall project management as well as conducting water quality and fisheries review of twenty proposed alternative transmission line corridors.

- Tiber Dam/Marias River Thermal Study. Collected and assessed data and managed development of a thermal model to predict effects on salmonid fishery due to hydropower development.

- Great Northern Ski Area Fatal Flaw Study. Collected and analyzed macroinvertebrate data as part of a fatal flaw study for a proposed ski area.

1979-1981: Environmental Planner, Montana Department of Natural Resources and Conservation, Helena Montana

Environmental Planner in the Water Resources Division. Primary responsibilities related to the development and implementation of state water policy, general water policy review dealing with water allocation, and inter-agency review of applications for reservation of water for instream flows. Assisted development of the state position on two controversial federal water projects as well as the Corps of Engineers National Hydropower Study. Participated in negotiations regarding water rights at a hydropower site. Provided expertise in the legal aspects of water rights administration and water allocation, and water quality-quantity integration.

1977-1979: Director, Flathead 208 Project, Kalispell, Montana

Duties were to administer and carry out the water quality program for this three county portion of western Montana. Had responsibility for budgeting, administration, planning and staff supervision. Staff varied from 1-4 people.

The Project involved implementation of the water quality plan for the drainage which was written during the initial two years of the project. Implementation included defining problems through research such as developing a nutrient budget for Flathead Lake to determine and control sources of nutrients causing eutrophication. Involved planning strategies to guide growth into those areas where water quality can be maintained. Activities included working with planning boards, county commissioners, conservation districts, legislators, and state and federal government officials in an effort to implement the solutions to water quality problems.

1975-1977: Staff Limnologist, Flathead 208 Project, Kalispell, Montana

Duties included design, field work, supervision and writing of a baseline physical, chemical, biological study of the North Fork of the Flathead River. Design, field work, supervision and writing of a study to determine impacts of irrigation, cattle and other agricultural activities on water quality. Research on potential energy developments and their effects on water quality.

1974-1975: Peace Corps Volunteer, Tehran, Iran

Responsible for the design and field work on a study to determine the impacts of road building and pulp mill construction on a river important to the fishery of the Caspian Sea.

1973-1974: Teaching Assistant, University of Montana, Missoula

Taught laboratory, lecture and field classes in limnology, zooplankton biology, ichthyology, general zoology and physiology.

1972-1973: Graduate Student, University of Montana, Yellow Bay

Studied the influences of forestry and agricultural practices on periphyton in a small Montana lake.

1971: Research Assistant, Sierra Nevada Aquatic Research Laboratory

Field and laboratory work associated with a study of calcium storage by Brook trout in high mountain lakes in the Sierra Nevada mountains of California.

Publications:

Hunter, C. J. 1974. Factors affecting the production of Tally Lake. M.S. Thesis, University of Montana, Department of Zoology. 56 pp.

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Affliations:

American Fisheries Society - Riparian Tax Incentive Bill Committee Chairman

Alberta Environment
Southwestern Alberta
Evaluation of the recreational potential of Beaverdam Lake, a reservoir under consideration for recreational enhancement.

Uranerz Exploration and Mining Limited
Key Lake, Saskatchewan
Evaluation of potential impacts along proposed all-weather road alignments and investigations of potential effects of a proposed uranium mine on fish populations.

1976 UNIVERSITY OF SASKATCHEWAN
Lecturer in Ichthyology

1974-76 DEPARTMENT OF TOURISM AND RENEWABLE RESOURCES
Fisheries Ecologist, Saskatchewan Fisheries Laboratory

Collection, analysis and presentation of data relevant to the management of aquatic resources in Saskatchewan lakes.

1971 CANADIAN WILDLIFE SERVICE

Estimation of reproductive success and monitoring movements of goldeye and walleye in the Peace-Athabasca Delta, Alberta.

PROJECT INVOLVEMENT

Alberta Environment
Oldman River Dam
Fisheries inventory and Instream Flow Incremental Methodology development for the Oldman River.

BP Resources Canada
Wolf Lake Heavy Oil Project
Fisheries and limnological studies and EIA preparation.

Alberta Environment
Drainage Inventory Studies
Assessment of fisheries concerns relative to proposed drainage programs.

Alberta Environment
Cold River, Saskatchewan
The collection of baseline fisheries information and preliminary impact assessment of a potential dam at the outlet of Cold Lake in Saskatchewan.

Interprovincial Pipe Line (NW) Ltd.
Normal Wells to Zama Oil Pipeline
Initiation of an aquatics monitoring program along the pipeline route.

Alberta Environment
Battle River, Alberta
The evaluation of the fisheries resource and identification of an appropriate instream flow needs study to determine the best flow regime for fisheries enhancement.

Alberta Environment
Sand and Wolf Rivers, Alberta
The collection of baseline fisheries information and preliminary impact assessment for a potential dam on the Sand River.

Gulf Canada Resources Inc.
Desan Oil Pipeline Alternatives
The identification and evaluation of sensitive areas along various alternative pipeline routings.

Interprovincial Pipe Line (NW) Ltd.
Norman Wells to Zama Oil Pipeline
Fisheries and water quality monitoring in relation to instream blasting in the Mackenzie River.

Gulf Canada Resources Inc.
Mt. Klappan, British Columbia
Stage I surface water investigations for the development of a coal property in north-central British Columbia.

Reid, Crowther & Partners Limited (Alberta Transportation)
Sarcee Trail Extension, Calgary, Alberta
Evaluation of alternative transportation routes in a corridor passing through the Sarcee Indian Reserve adjacent Calgary.

Alberta Environment
Provide third party advice on the environmental acceptability of applications for water-related developments.

Alberta Environment
Development of an underwater closed-circuit camera and recording system.

Gulf Canada Resources Inc.
Rocky Mountain House, Alberta
Conduct water quality investigations in the drainage adjacent the Strachan Gas Plant.

Gulf Canada Resources Inc.
Mt. Klappan, British Columbia
Preparation of the environmental component for a prospectus for a coal property in north-central British Columbia.

TransAlta Utilities/Alberta Power/Alberta Utilities and Telecommunications
Slave River, Northwest Territories
Fisheries investigation of the Slave River from Fort Smith to Great Slave Lake in relation to the potential hydro development of the Slave River.

PanCanadian Petroleum Limited
Lake Newell, Alberta
Investigations of aquatic habitats with emphasis on spring and fall spawning habitat utilization in Lake Newell in relation to a drilling program in Jackfish Bay.

Alberta Environment
Dickson Dam, Red Deer River, Alberta
A fisheries investigation to determine standing stocks of fish, available habitat prior to dam closure, and preferred habitats of the fauna through the use of the Instream Flow Incremental Methodology.

Strong Hall & Associates (Alberta Environment)
South Saskatchewan River Basin, Alberta
Development of environmental assessment parameters for a conceptual approach to water management options for the South Saskatchewan River Basin.

Alberta Environment
Little Bow River, Alberta
Fisheries investigations to assess fisheries species composition and aquatic habitat in the Little Bow River in relation to a proposed water diversion project.

Foothills Pipe Lines (South Yukon) Ltd.
Alaska Highway Gas Pipeline, Yukon Territory
Fisheries data collection, analysis, advisory services, preparation of environmental impact statements and testimony before the Federal Environmental Assessment and Review Panel.

Alberta Environment
Proposed Gwynne Reservoir, Alberta
Fisheries study of spring spawning movements, spawning locations and numbers of spawners in the region of the proposed reservoir.

Husky Oil Operations Ltd.
Plains Oil Upgrader, Saskatchewan
Collection of fisheries and water quality information relevant to site selection for the proposed upgrader and associated pipeline routes.

Alberta Environment
South Saskatchewan River Basin, Alberta
Develop a methodology for evaluating the effects of water management strategies on the fisheries resources within the South Saskatchewan River Basin.

Alberta Environment
Proposed Badger Lake Reservoir, Alberta
Preparation of the Initial Environmental Evaluation.

Alberta Environment
Expert advice on Instream Flow Methodology.

Confidential Client
Northeastern British Columbia
Evaluate the fishery of drainages on petroleum leases in northeastern British Columbia.

Alberta Energy and Natural Resources
Bow River Tributaries
A study to determine the movement patterns of rainbow trout fry in Ware and Threepoint creeks and the Sheep River.

Alberta Environment
Fawcett Lake, Alberta
Monitoring fish movements in Fawcett River and the evaluation of a Denil 2 fishway at the outlet of Fawcett Lake.

Alberta Environment
Carseland-Bow Canal
Determine the toxicity of the herbicide Magnacide H to native fishes in the Carseland-Bow Canal.

Dome Petroleum Limited
Caroline Miscible Flood Pipeline, Alberta
Fisheries data collection along alternative pipeline routes.

Alberta Transportation
Grande Cache to Grande Prairie Highway, Alberta
Fisheries mitigation study.

Nova, An Alberta Corporation
Alaska Project Division
Alaska Highway Gas Pipeline, Alberta
Fisheries data collection and analysis, monitoring studies and advisory services.

Shawinigan Engineering Consultants Limited
Teslin River Hydro Project, Yukon Territory
Fisheries data assimilation and report preparation.

Nova, An Alberta Corporation
Grande Prairie Lateral and Elmworth Loop Pipelines, Alberta
Fisheries data collection, analysis and advisory services.

Northern Pipeline Agency
Alaska Highway Gas Pipeline, Southern British Columbia
Fisheries data collection and advisory services.

PUBLICATIONS AND REPORTS:

Fernet, D.A. and S.M. Matkowski. 1986. Fish distribution, abundance, critical habitats and relationships with streamflow downstream of the Oldman River damsite. Prepared for Planning Division, Alberta Environment, Edmonton, Alberta. 148+ pp.

Fernet, D.A. and S.M. Matkowski. 1986. Strachan water quality, 1985 Program. Prepared for Gulf Canada Resources, Calgary, Alberta. 35+ pp.

Fernet, D.A. 1986. Mount Klappan coal property 1985 surface water program. Prepared for Gulf Canada Resources Inc., Calgary, Alberta. 21 pp + app.

Fernet, D.A. and S.M. Matkowski. 1985. An inventory of aquatic resources in the vicinity of the Wolf Lake Development. Prepared for BP Resources Canada Limited, Calgary, Alberta. 45 pp.

McLeod, C., G. Ash, D. Fernet and J. O'Neill. 1985. Fall fish spawning habitat survey. Prepared for Slave River Hydro Study Group, Edmonton, Alberta. 102 pp + app.

Fernet, D.A. 1985. Aquatic monitoring survey Norman Wells to Zama Pipeline, July, 1985. Prepared for Interprovincial Pipe Line (NW) Ltd., Edmonton, Alberta. 16 pp + app.

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Fernet, D.A. 1985. Inventory of Alberta's drainage requirements, Shoal Creek Basin fisheries component. Prepared for Interdepartmental Steering Committee on Drainage. 18 pp.

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McLeod, C., L. Hildebrand and D. Fernet. 1985. Sand River fisheries study, spring spawning migrations and impact assessment of the proposed site B dam. Prepared for Planning Division, Alberta Environment, Calgary, Alberta. 87 pp + app.

Fernet, D.A., G.A. Ash and S.M. Matkowski. 1985. Investigations of the Battle River fishery relative to the potential effects of flow augmentation. Prepared for Planning Division, Alberta Environment, Edmonton, Alberta. 74 pp + app.

Fernet, D.A. 1985. Inventory of Alberta's drainage requirements Lalby Creek Basin fisheries component. Prepared for Interdepartmental Steering Committee on Drainage. 18 pp.

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Fernet, D.A., D.A. Young and D.S. Kerr. 1984. Biophysical investigations in Jackfish Bay, Lake Newell, spring and summer, 1984. Prepared for PanCanadian Petroleum Limited, Calgary, Alberta. 47 pp + app.

Fernet, D.A. 1984. Fisheries and water quality monitoring in relation to an instream blast in the Mackenzie River. Prepared for Interprovincial Pipe Line (NW) Ltd., Edmonton, Alberta. 16 pp + app.

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Ullman, P.M. and D.A. Fernet. 1984. Strachan water quality 1983 program. Prepared for Gulf Canada Resources Inc., Calgary, Alberta. 43 pp + app.

Young, D.A., D.A. Fernet, D.S. Kerr. 1984. Biophysical Investigations in Jackfish Bay, Lake Newell, Fall 1983. Prepared for Pan-Canadian Petroleum Limited, Calgary, Alberta. 56 pp + app.

D.A. Young, D.A. Fernet and P.M. Ullman. 1983. An environmental overview of the Kwokwullie Lake Area northeastern British Columbia. Prepared for Gulf Canada Resources Inc., Calgary, Alberta. 28 pp.

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Fernet, D.A. and W.J. Wareham. 1983. A spring aquatics survey of the Kwokwullie Lake drainage. Prepared for Gulf Canada Resources Inc., Calgary, Alberta. 26 + pp.

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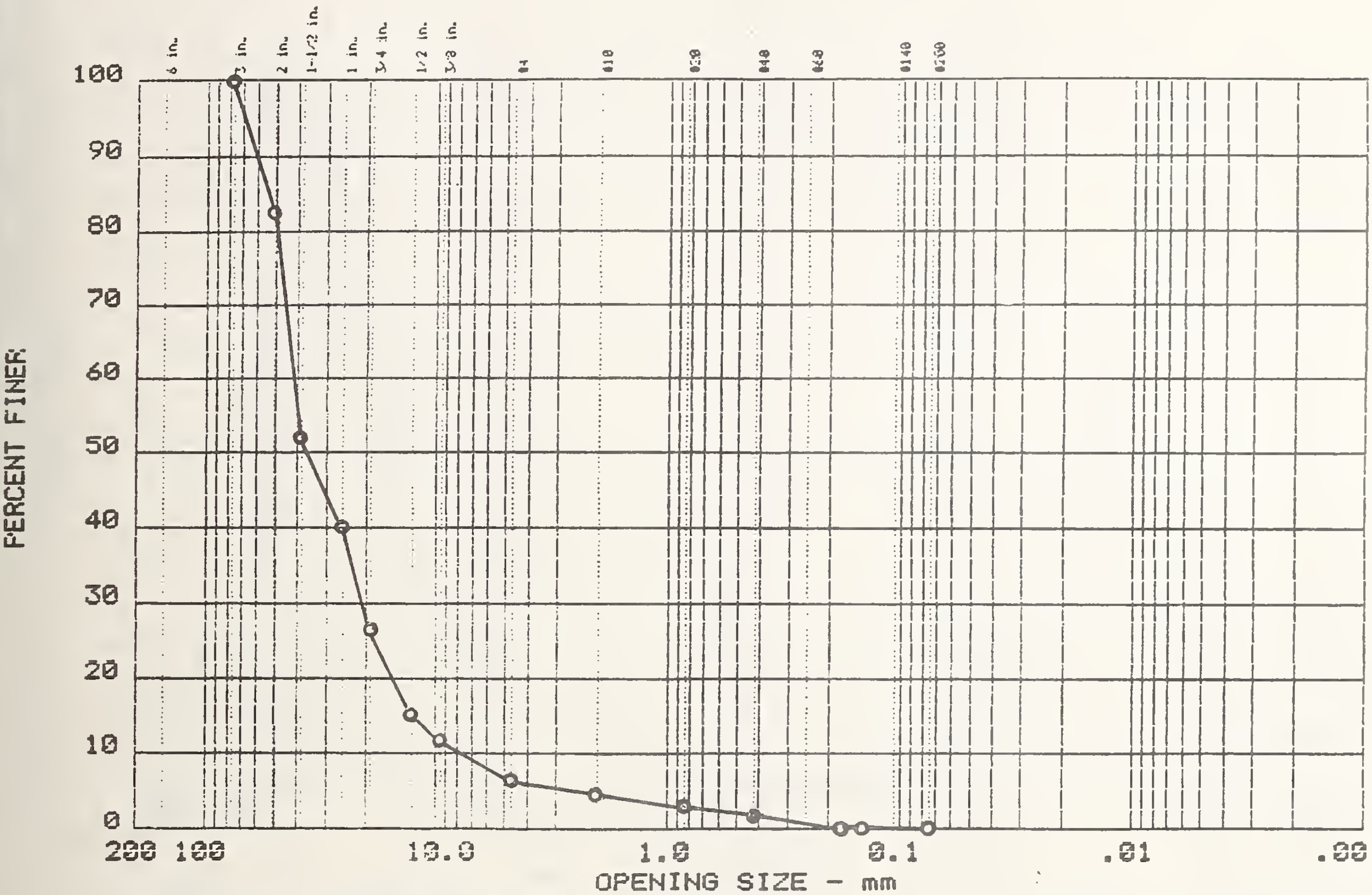
- APPENDIX B -

Substrate Composition at Observed Spawning Sites

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	93.6		6.4	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GW		Gran.	N.P.	38.100	20.5551	8.18314	1.3552	4.6559

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: Middle Creek Dam
O Location: Field no. 17

Date: 8-11-86

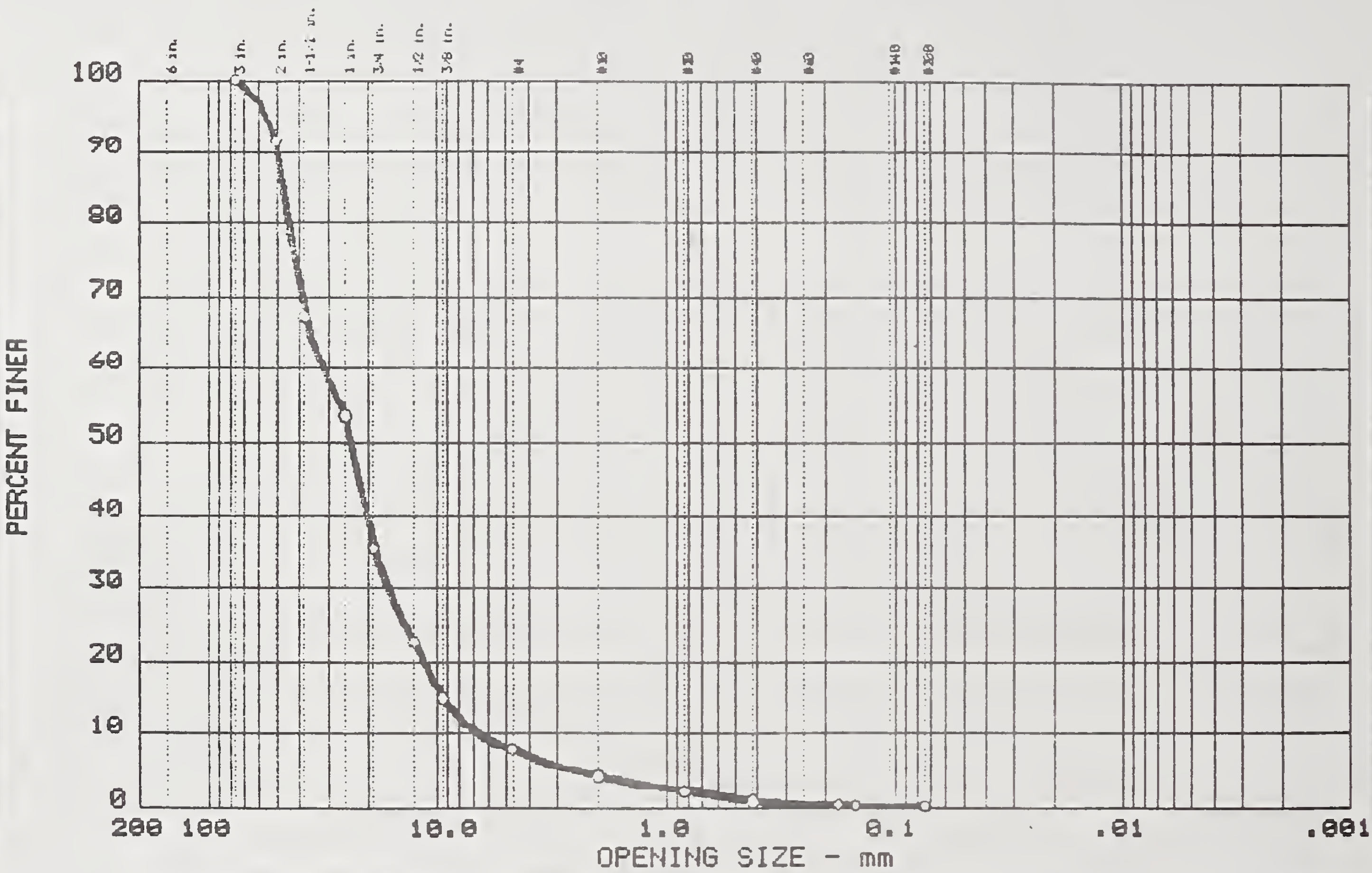
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by C. Hunter

Plate No. 17

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	92.0	7.9	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GW		Gran	N.P.	31.26	16.520	6.5766	1.33	4.8

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #57

Date: 8-11-86

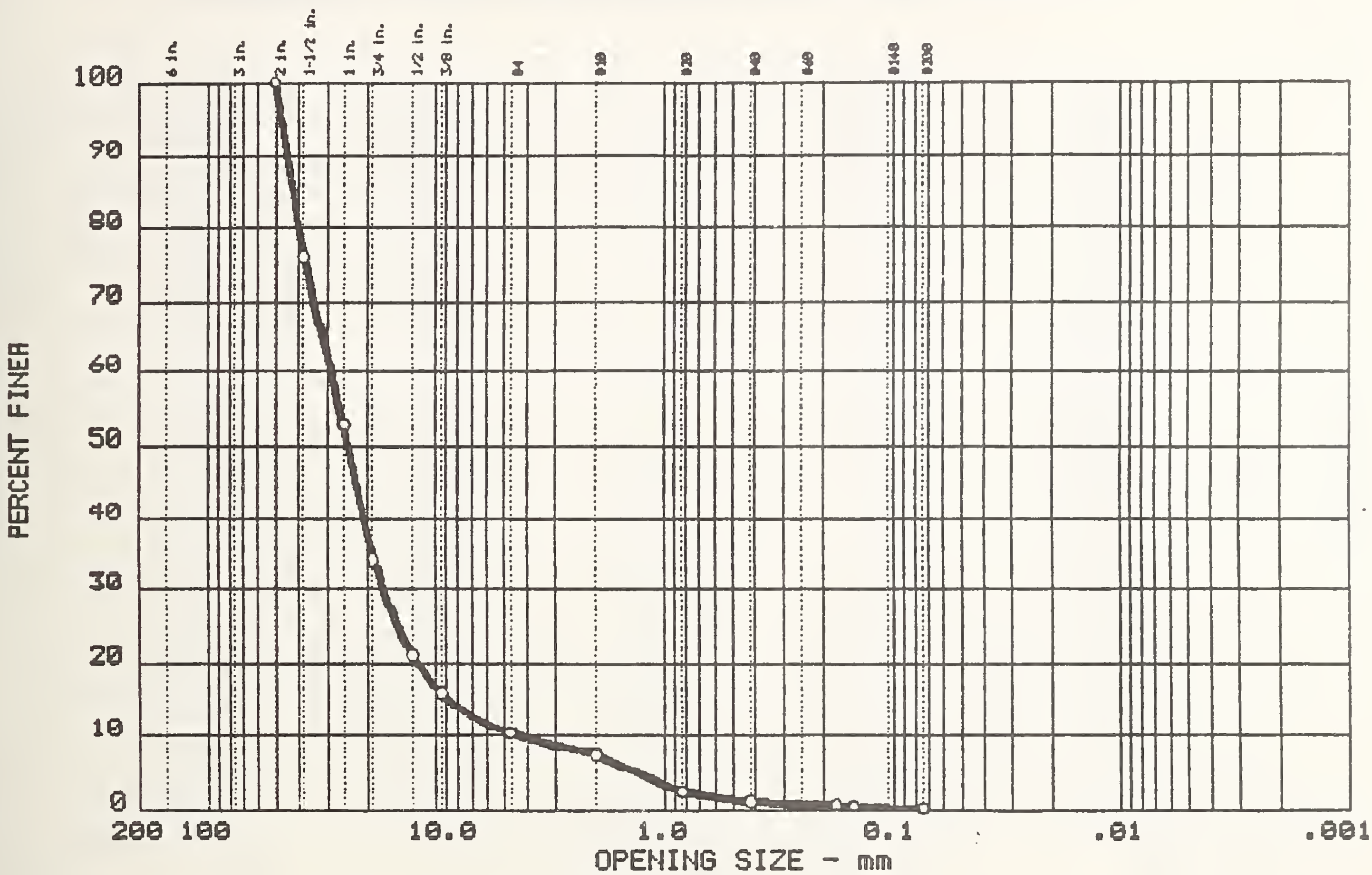
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 57

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	89.5	10.4	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GW		Gran	N.P.	28.94	17.239	4.2316	2.43	6.8

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
O Location: Field no 22

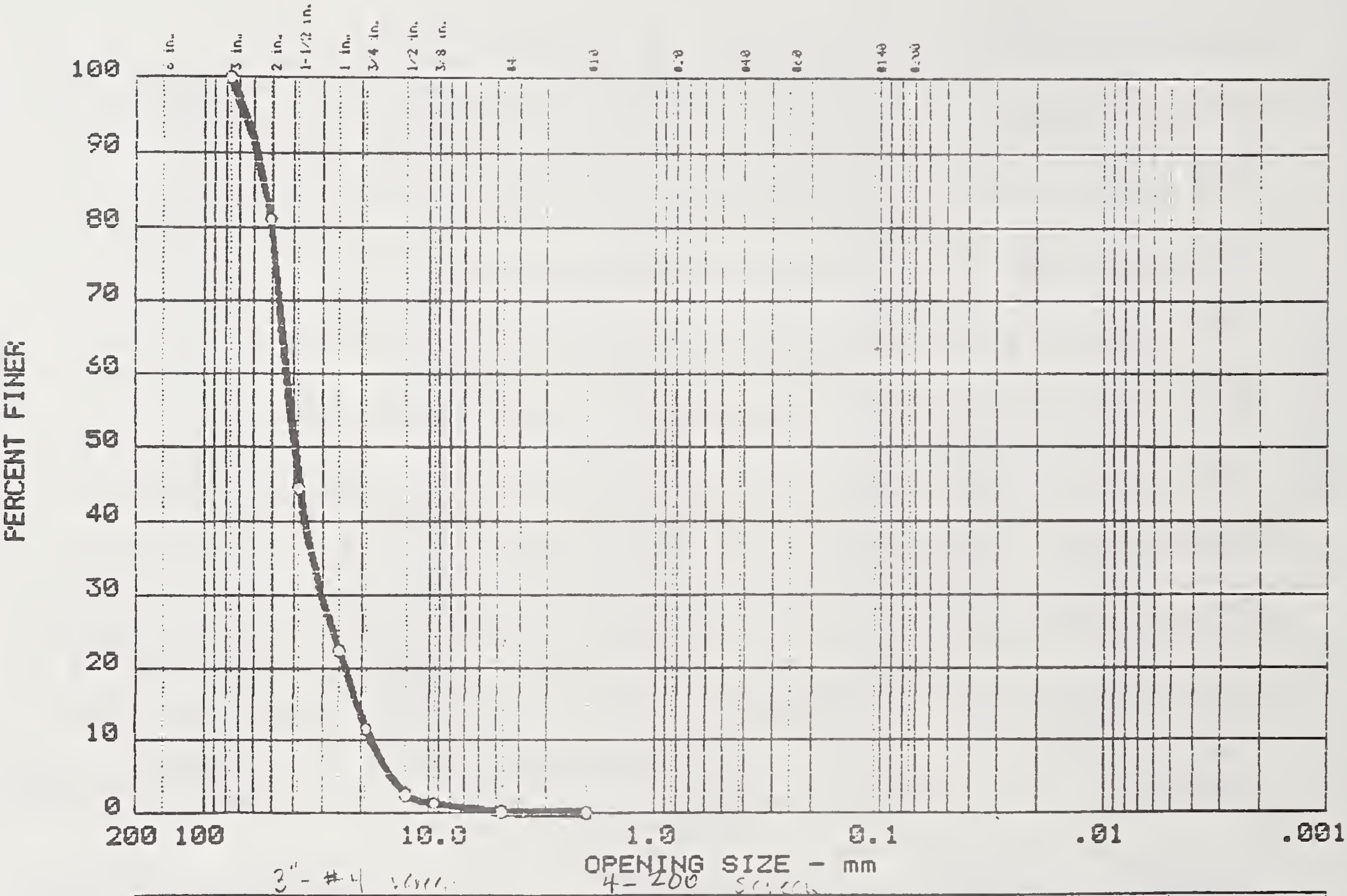
Date: 8-11-86

GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:
Sampled by Chris Hunter

Plate No. 22

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	99.8	0.2		

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GP		Gran	N. P.	43.00	30.584	18.0094	1.21	2.4

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087-121
Project: Middle Creek Dam
O Location: Field no. 5

Date: 8-11-86

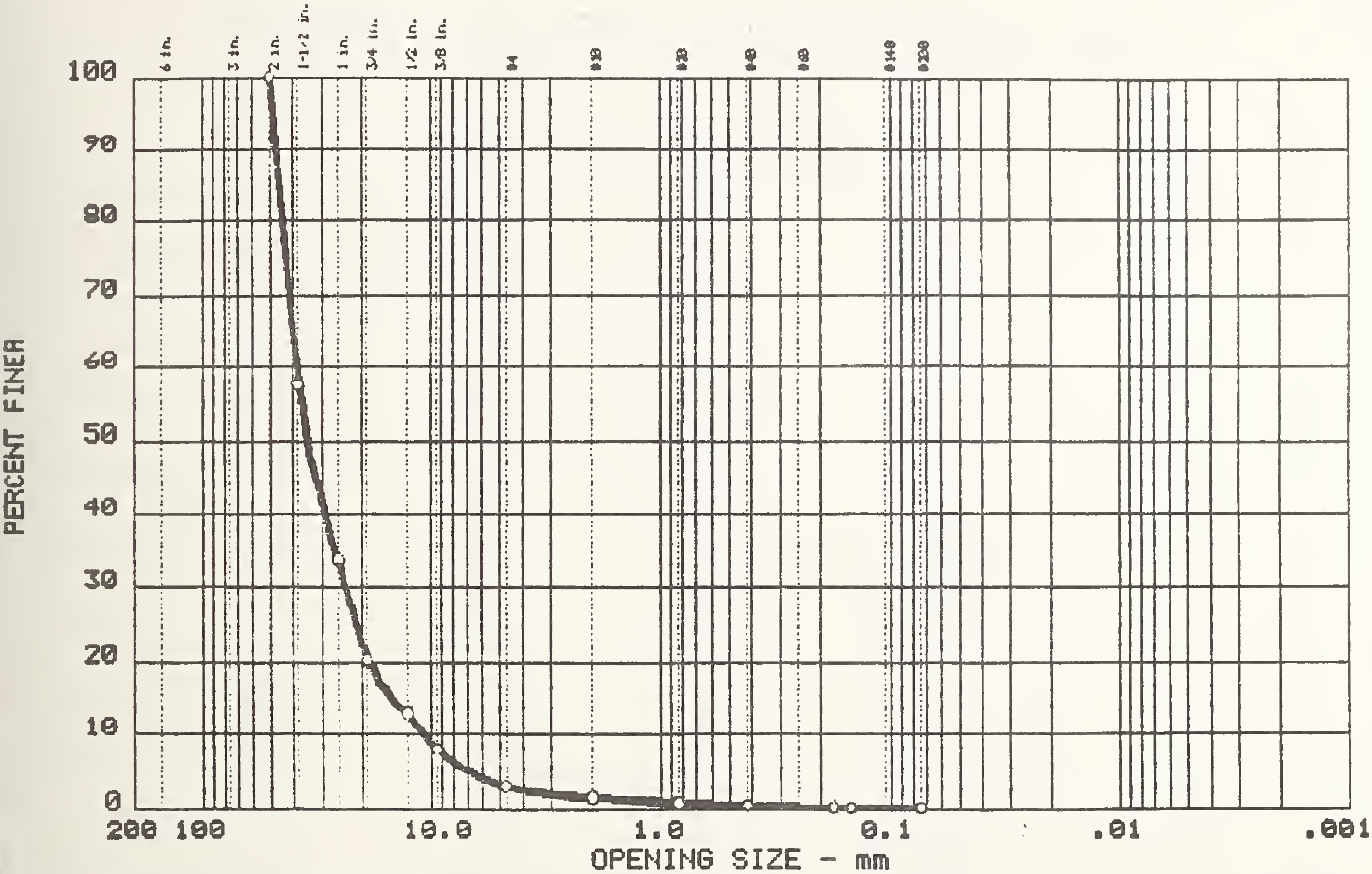
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by C. Hunter

Plate No. 5

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	97.0	3.0	0.0	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GP		Gran	N.P.	30.10	23.600	10.6640	1.37	3.6

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #8

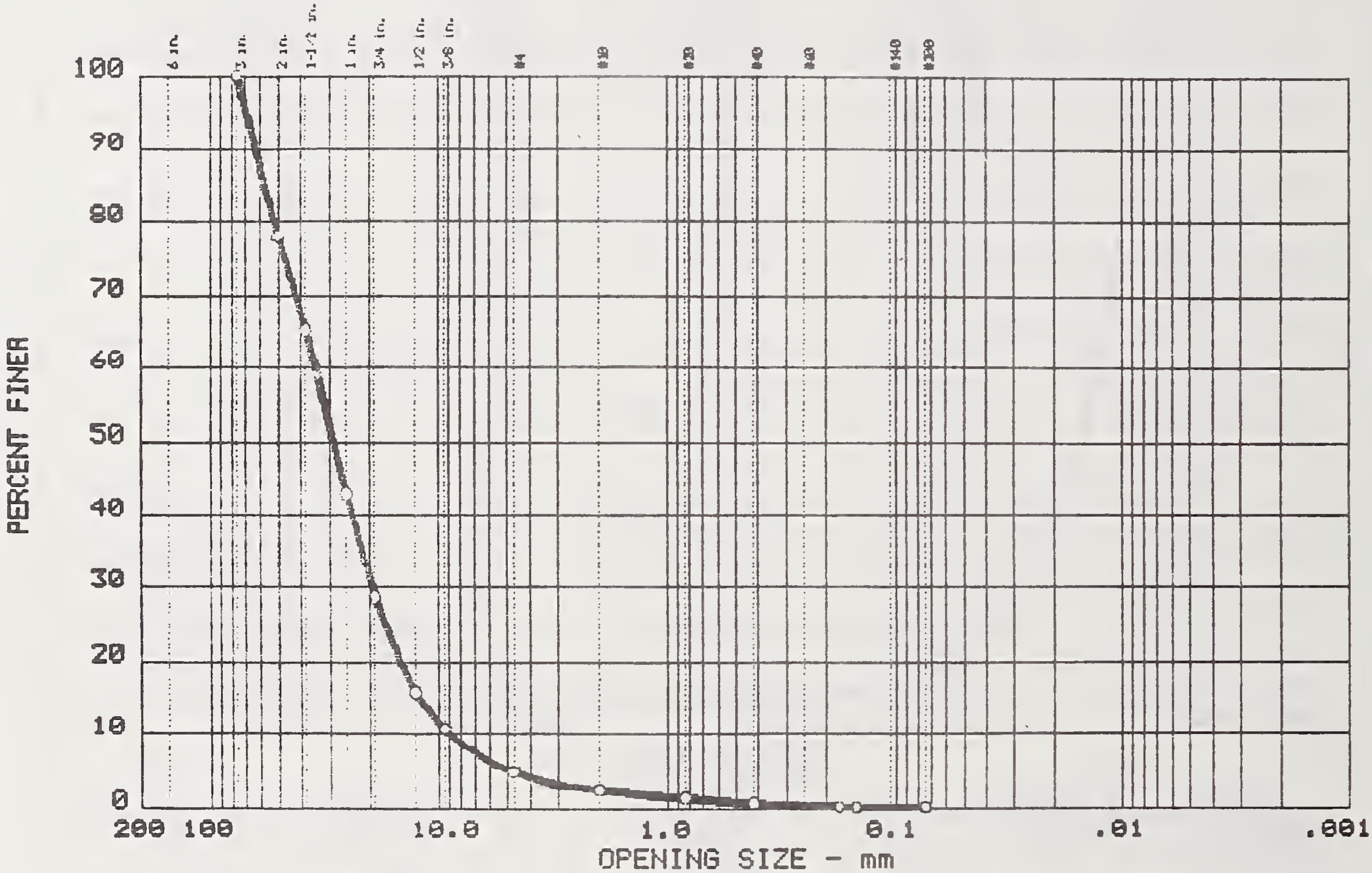
Date: 8-11-86

GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:
Sampled by Chris Hunter

Plate No. 8

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	95.0	4.9	0.0	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
o	GP		Gran	N.P.	34.55	19.500	8.8512	1.25	3.9

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #11

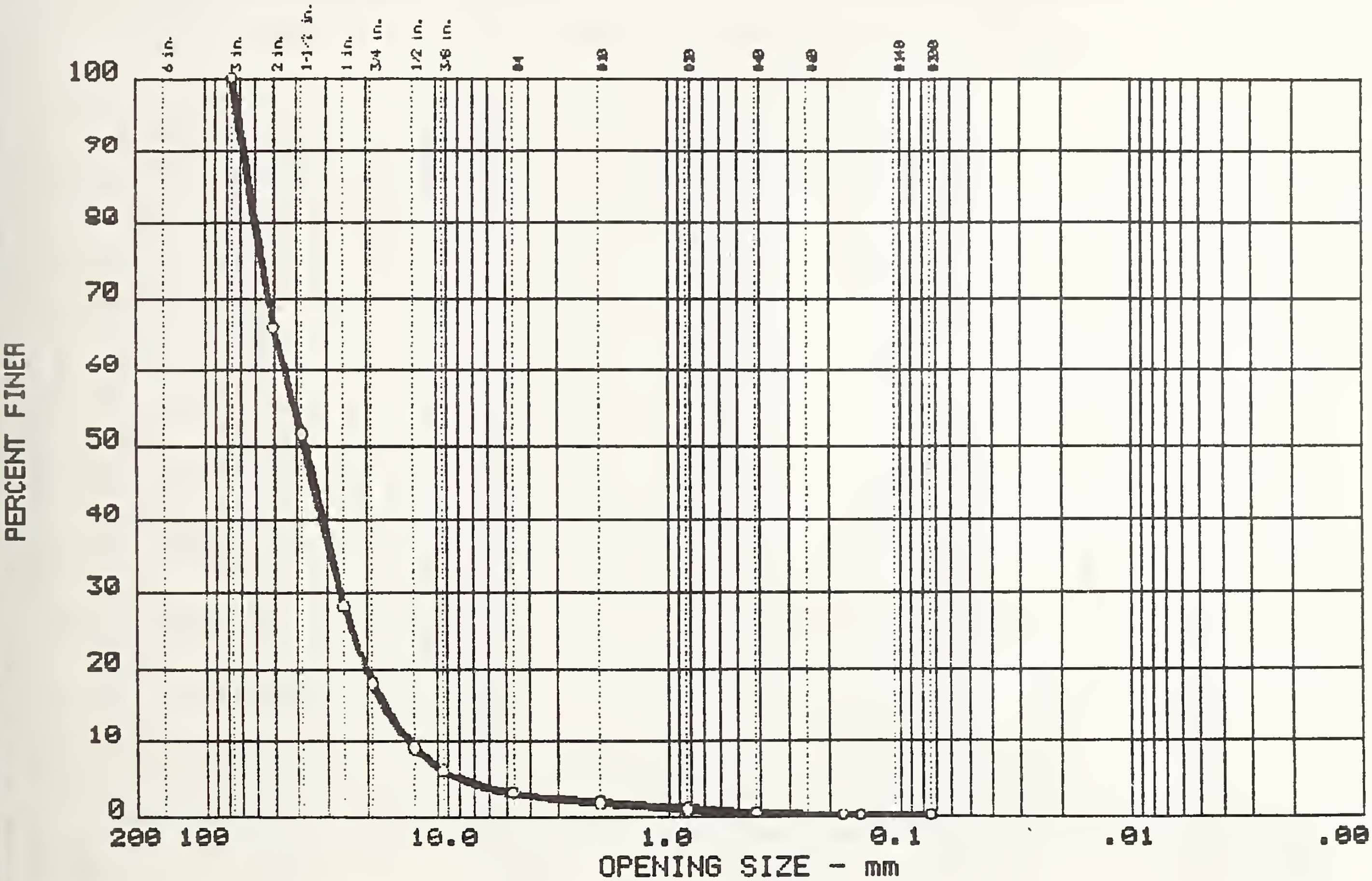
Date: 8-11-86

Remarks:
Sampled by Chris Hunter

GRAIN SIZE DISTRIBUTION TEST REPORT

Plate No. 11

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	96.8	3.1	0.0	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GP		Gran	N.P.	45.45	26.152	13.2587	1.14	3.4

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
O Location: Field #14

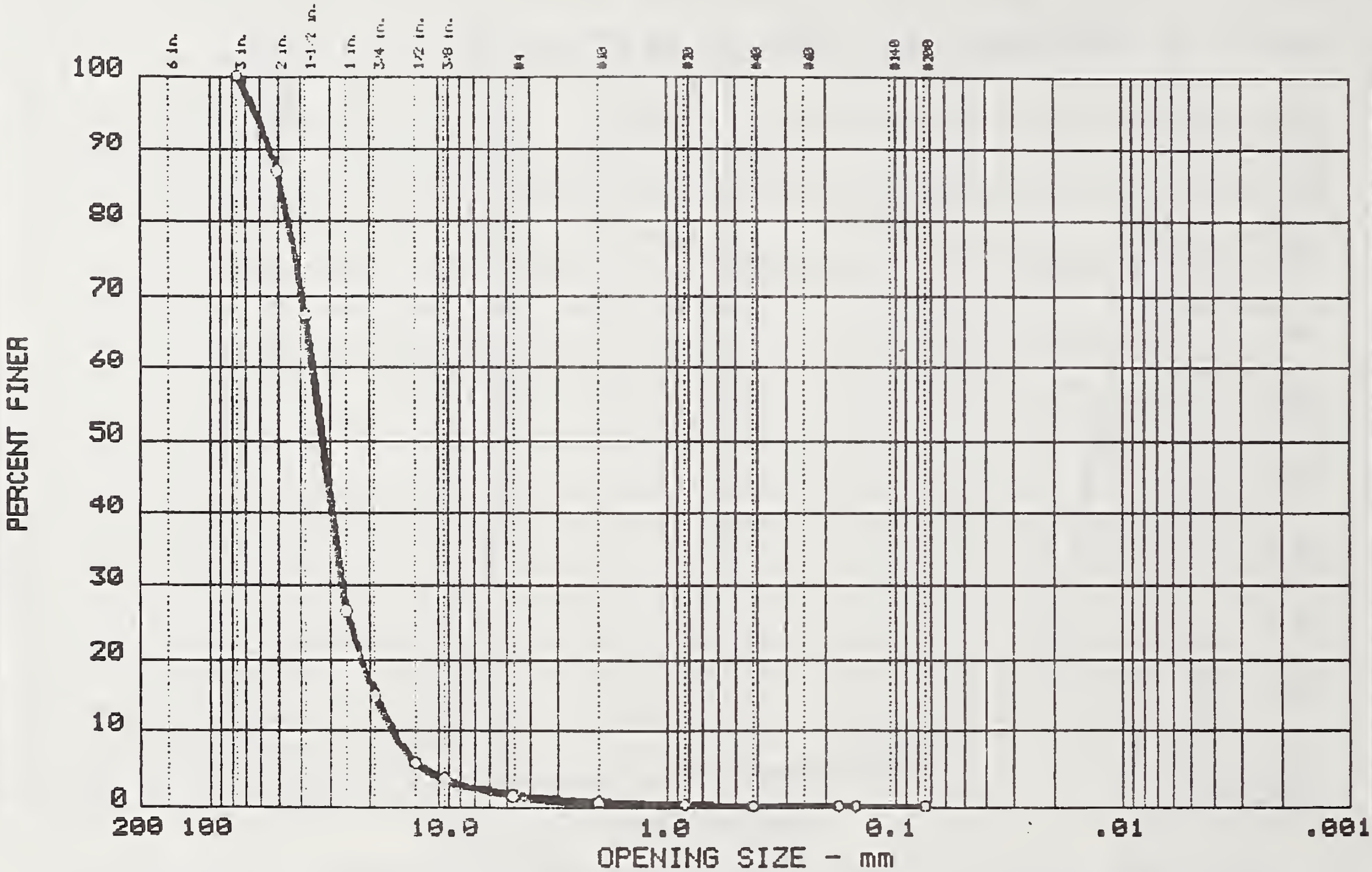
Date: 8-11-86

GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:
Sampled by Chris Hunter

Plate No. 14

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	98.5	1.5	0.0	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GP		Gran	N.P.	35.40	25.400	16.0262	1.13	2.2

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #27

Date: 8-11-86

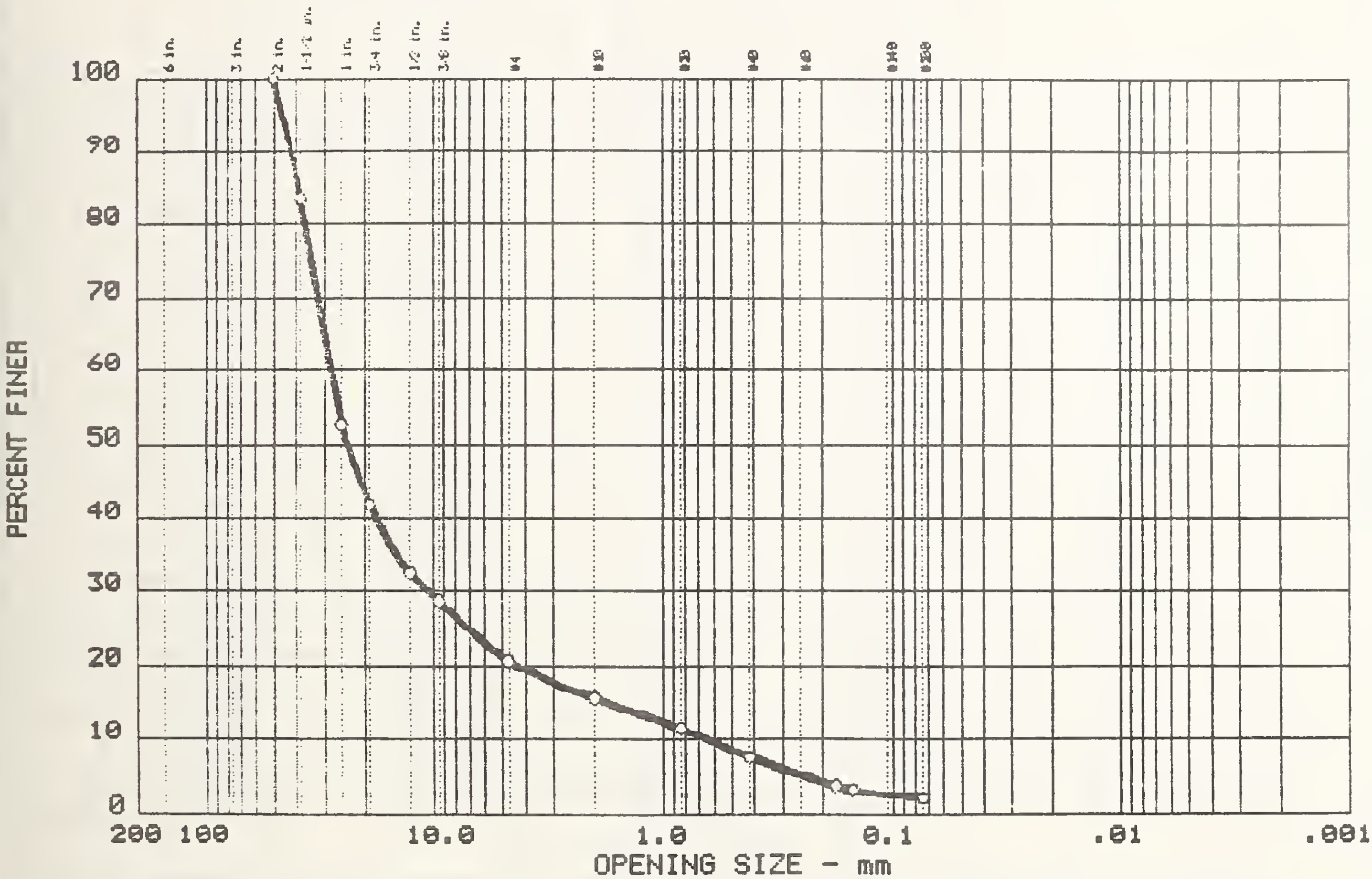
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 27

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	79.5	18.4	2.2	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
o	GP		Gran	N.P.	20.10	10.593	0.6303	6.24	44.2

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel with Sand	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #52

Date: 8-11-86

GRAIN SIZE DISTRIBUTION TEST REPORT

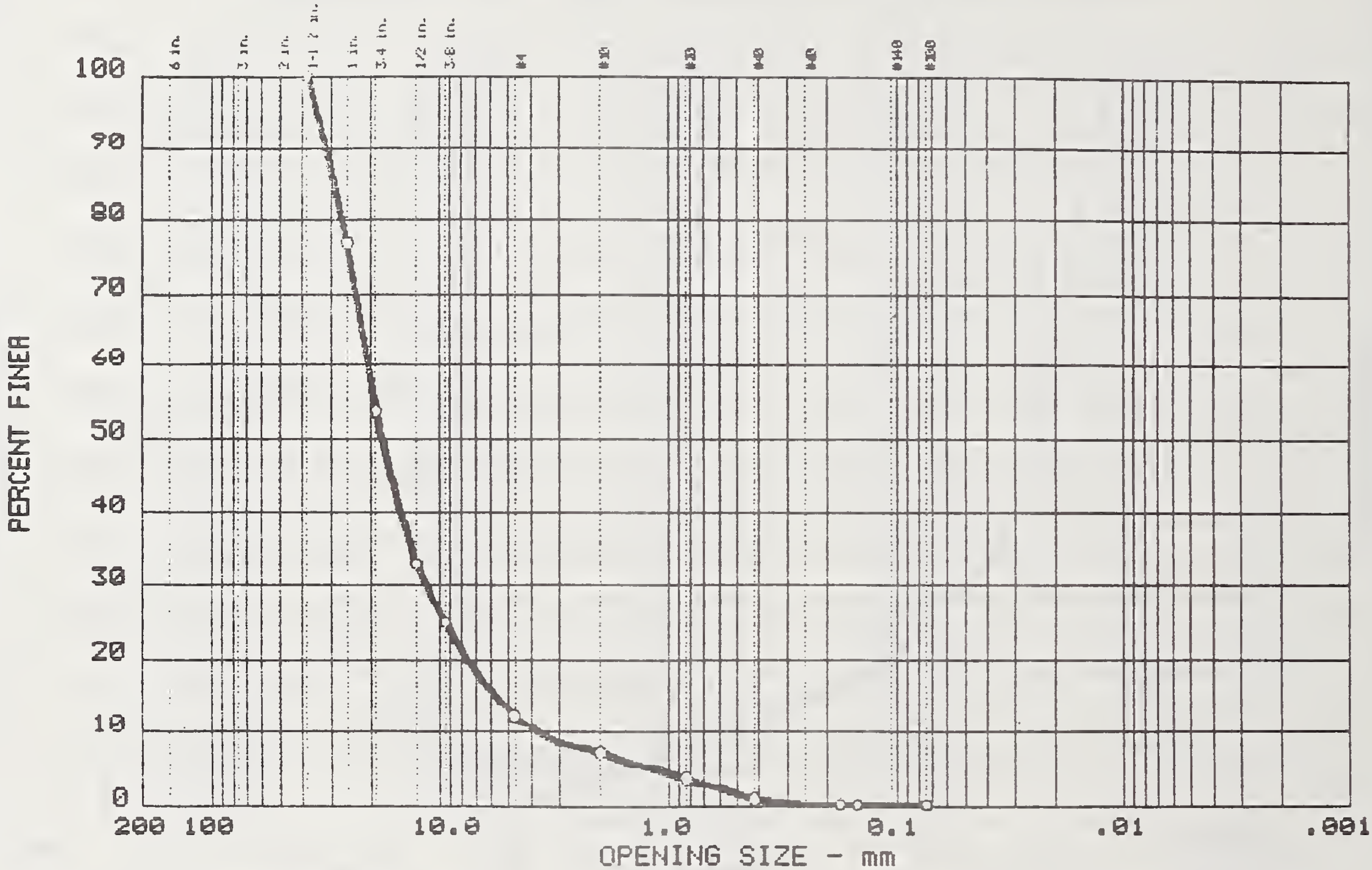
Remarks:

Sampled by Chris Hunter

Area was high and dry

Plate No. 52

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	87.8	12.2	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GW		Gran	N.P.	20.63	11.574	3.6602	1.77	5.6

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
O Location: Field #45

Date: 8-11-86

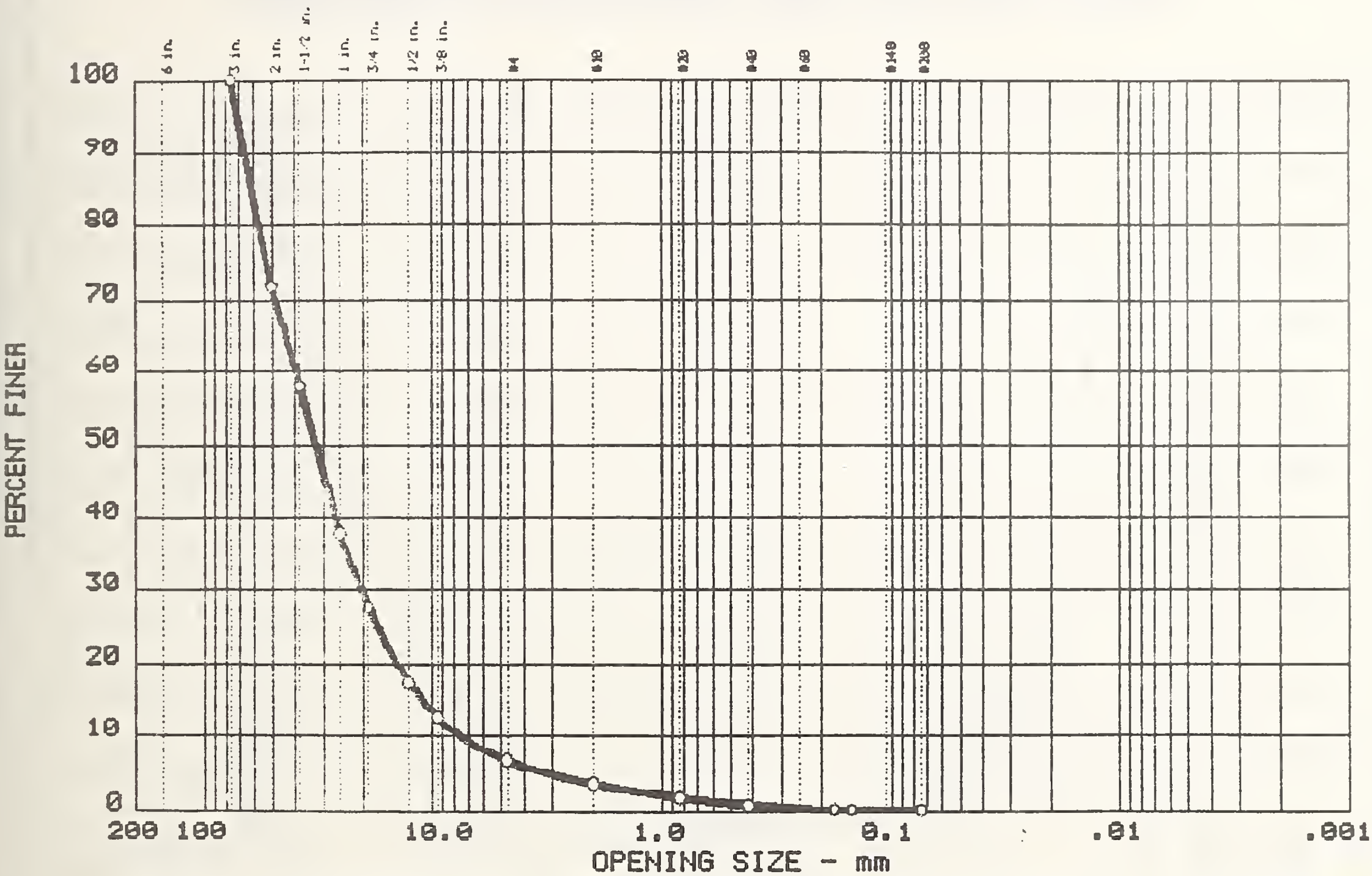
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 45

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	93.2	6.8	0.0	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GW		Gran	N.P.	30.10	20.461	7.5140	1.46	5.1

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #40

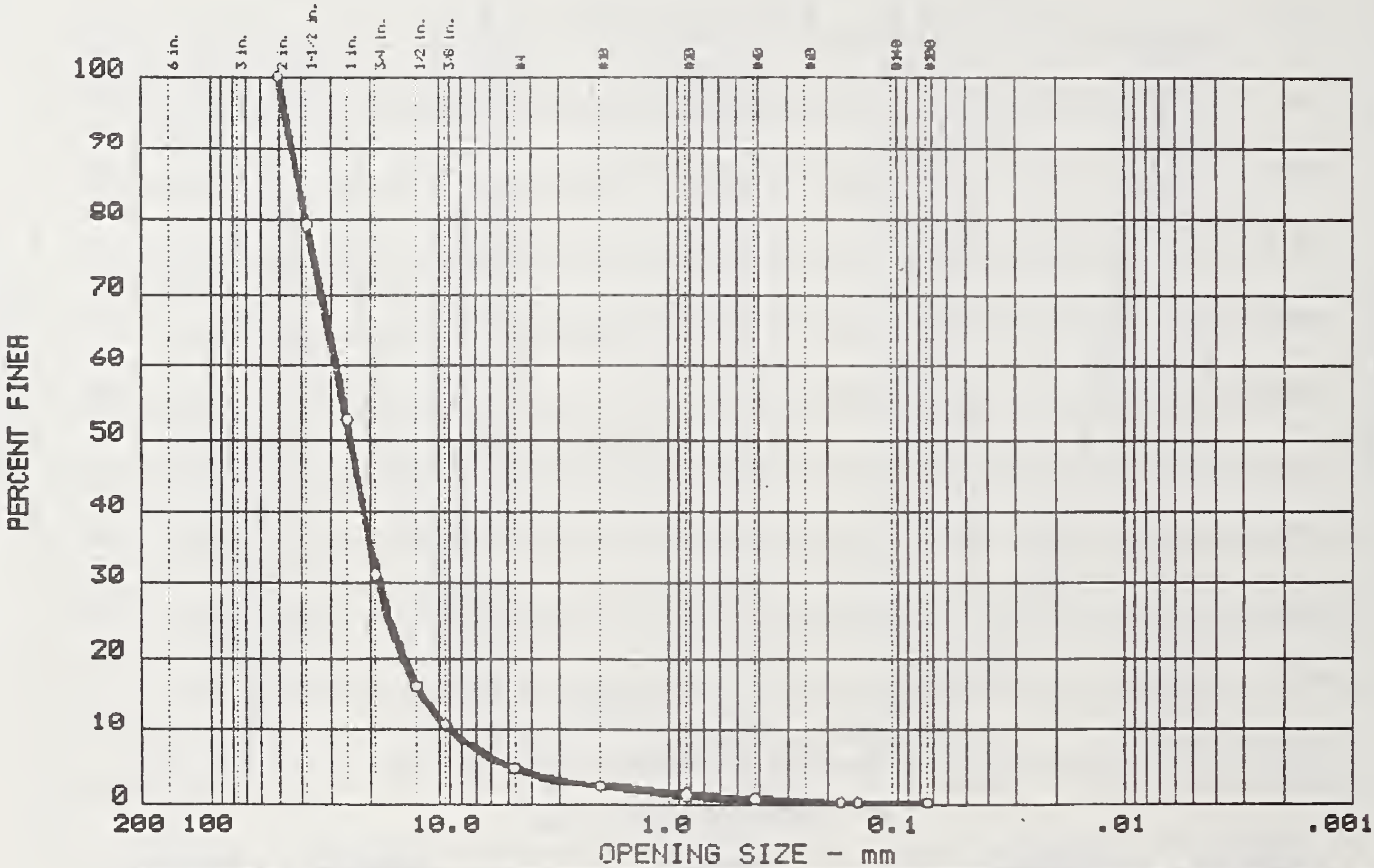
Date: 8-11-86

GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:
Sampled by Chris Hunter

Plate No. 40

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	95.1	4.8	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GP		Gran	N.P.	20.31	10.493	8.8512	1.36	3.2

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
O Location: Field #32

Date: 8-11-86

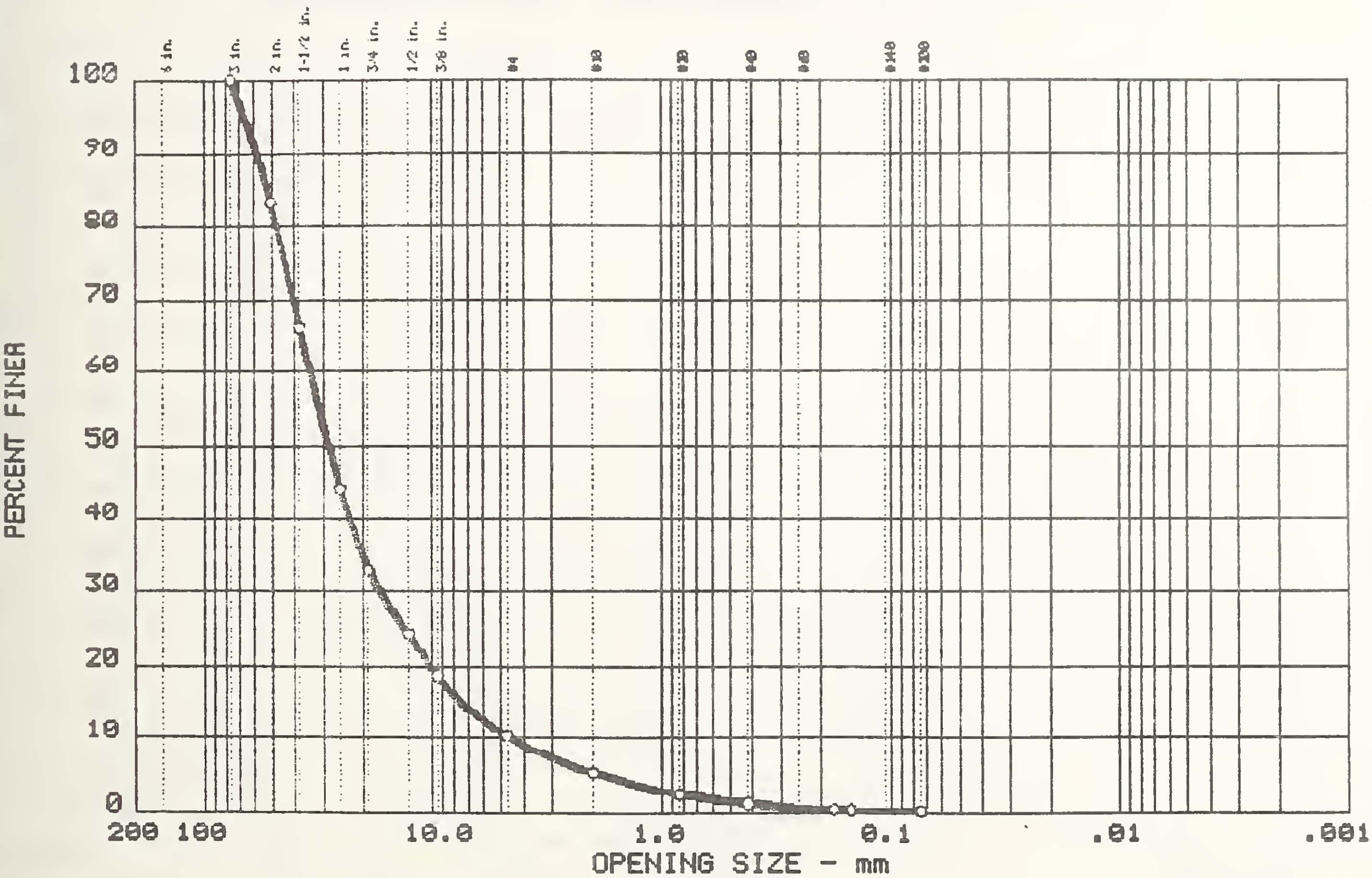
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 32

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	89.6	10.4	0.0	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
o	GW		Gran	N.P.	34.20	16.943	4.5002	1.86	7.6

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #35

Date: 8-11-86

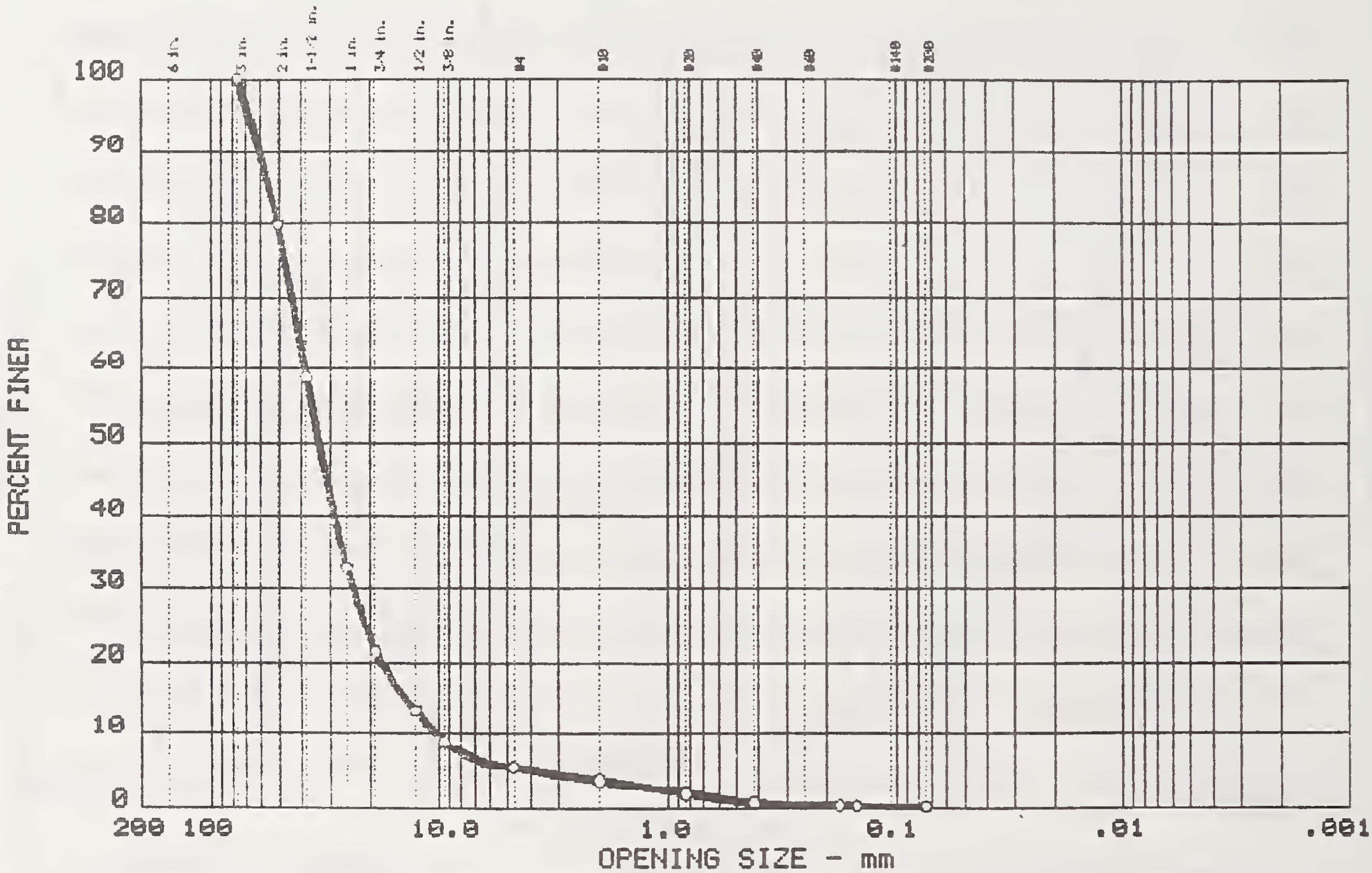
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 35

GRAIN SIZE DISTRIBUTION TEST REPORT



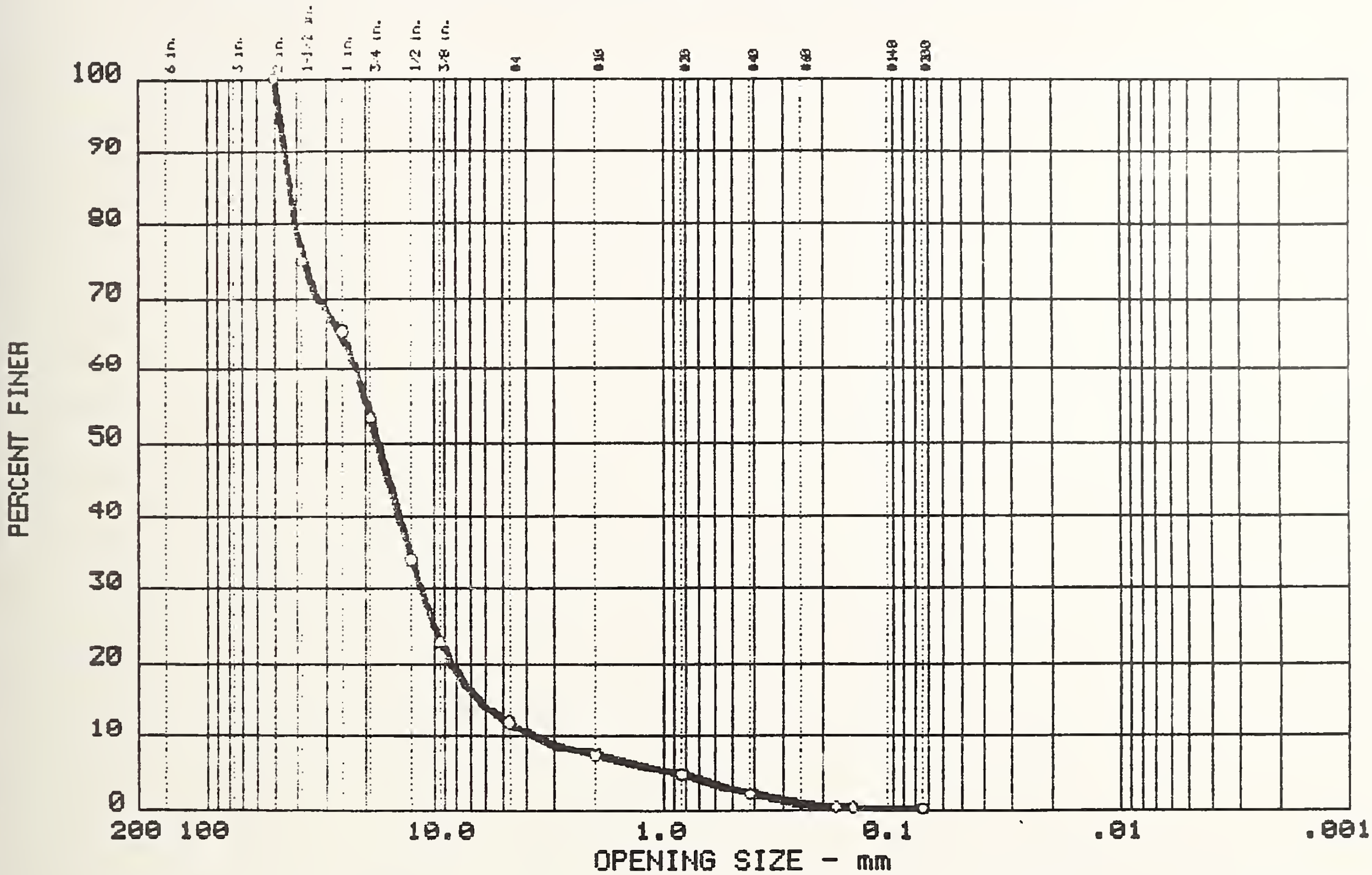
	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	94.6	5.3	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
O	GW		Gran	N.P.	38.10	23.764	9.5249	1.56	4.0

MATERIAL DESCRIPTION	TYPE OF TEST
O Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121 Project: MIDDLE CREEK DAM O Location: Field #43 Date: 8-11-86	Remarks: Sampled by Chris Hunter
GRAIN SIZE DISTRIBUTION TEST REPORT	Plate No. 43

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	88.0	12.0	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
o	GW		Gran	N.P.	22.13	11.402	3.6308	1.64	6.1

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #44

Date: 8-11-86

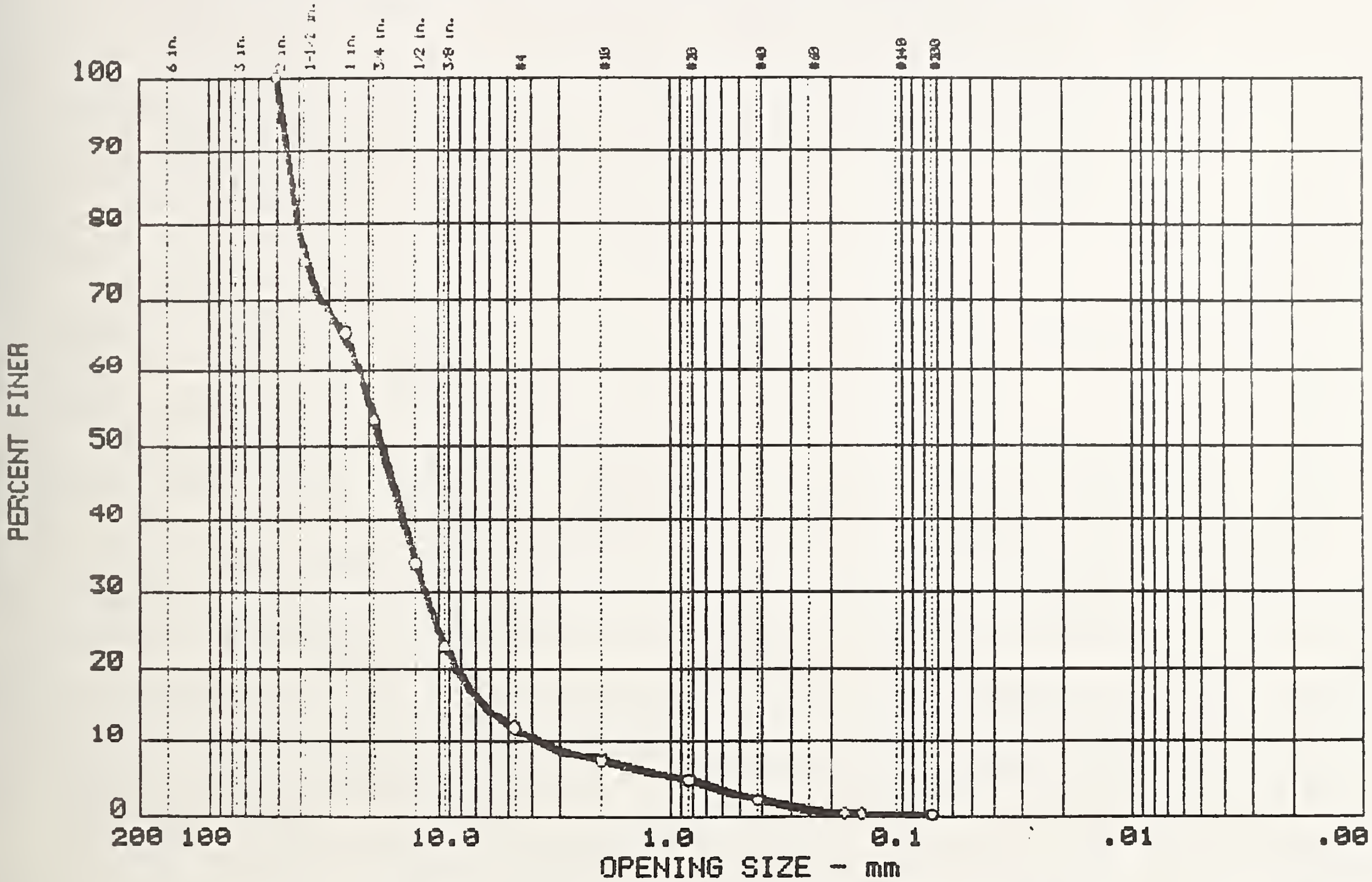
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 44

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	38.0	12.0	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
o	GW		Gran	N.P.	22.13	11.402	3.6308	1.64	6.1

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #44

Date: 8-11-86

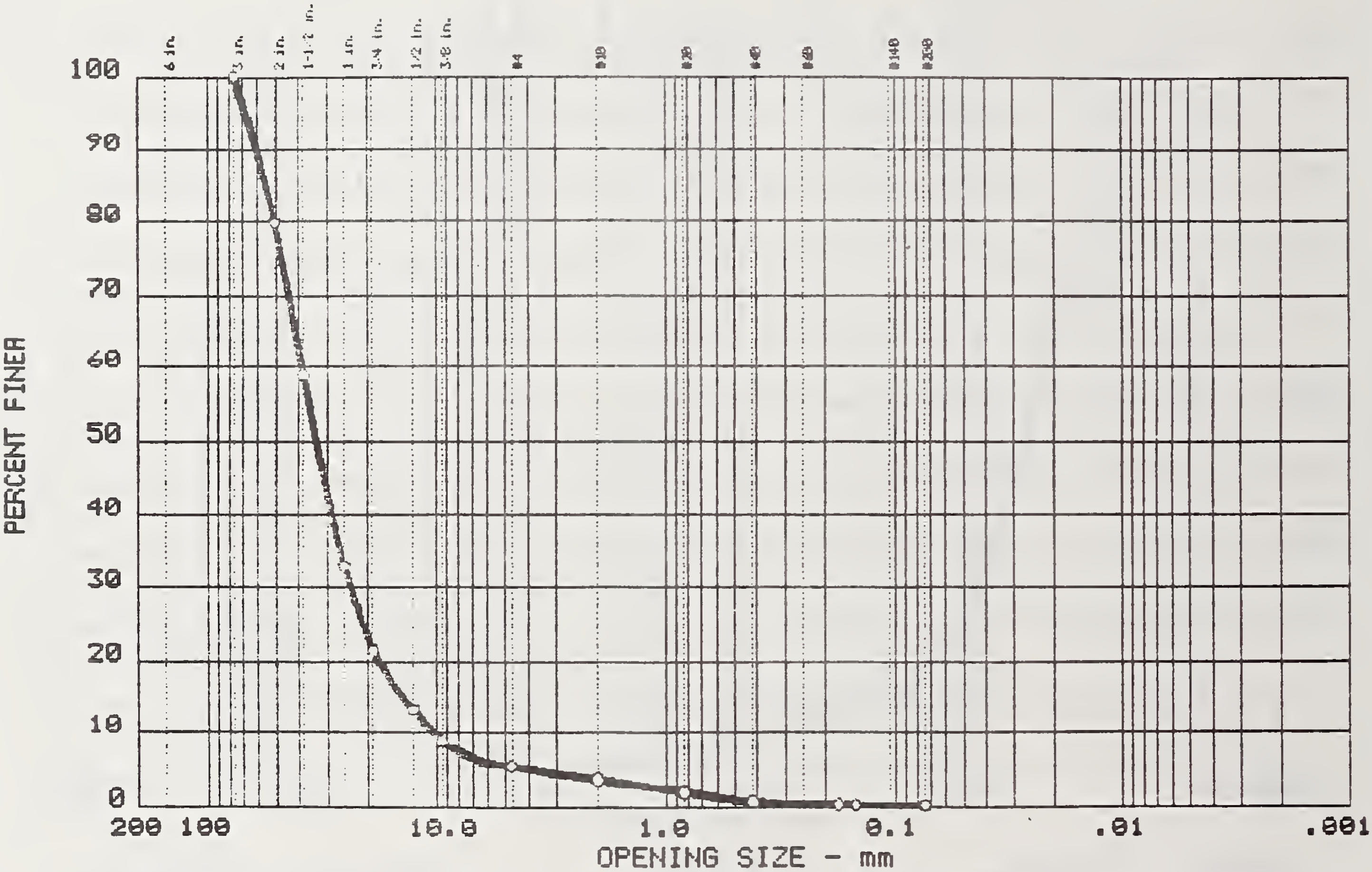
GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 44

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	0.0	94.6	5.3	0.1	

	USCS Classification	% COLLOIDS	LL	PI	D_{60}	D_{30}	D_{10}	C_c	C_u
o	GW		Gran	N.P.	38.10	23.764	9.5249	1.56	4.0

MATERIAL DESCRIPTION	TYPE OF TEST
o Gravel	ASTM D 422-63(72) Mechanical analysis

Project No.: 8M087.121
Project: MIDDLE CREEK DAM
o Location: Field #43

Date: 8-11-86

GRAIN SIZE DISTRIBUTION TEST REPORT

Remarks:

Sampled by Chris Hunter

Plate No. 43

- APPENDIX C -

Depth/Velocity Measurements at Observed Spawning Sites

	1	2	3	4	5
1	DEPTH (FT)	6/10 VELOCITY	NOSE VELOCITY		
2					
3					
4	2.45	4.35	1.2		
5	1.44	1.75	0.9		
6	1.41	4.5	2.4		
7	1.01	3.3	2.4		
8	1.1	1.68	1		
9	1.35	3.35	1.25		
10	1.35	3.35	1.25		
11	1.18	3.4	1.1		
12	1.05	3.3	1.94		
13	1.05	3.3	2.05		
14					
15	1.16	4.26	1.99		
16	1.19	4.05	2.26		
17	1.16	2.8	1.9		
18	1.45	5.1	2.3		
19	1.51	3.85	1.06		
20	1.38	4.22	2.9		
21	1.4	4.26	2.24		
22	1.38	3.83	1.13		
23	1.25	2.35	1.43		
24	1.13	3.55	1.36		
25	1.13	3.55	1.36		
26	1.34	3.53	1.29		
27	1.1	3.3	1.9		
28	1.1	3.4	1.52		
29	1.25	4.03	2.06		
30	1.05	3.35	2.04		
31	1.05	3.35	2.04		
32	1.05	3.35	2.04		
33					
34	1.05	2.89	1.98		
35	1.03	3.42	1.87		
36	1.31	3.82	2.47		
37	1.25	4.04	1.2		
38					
39					
40					
41					
42	1.15	3.8	2.55		
43					
44					
45	1.7	4.24	1.75		
46					
47					
48					
49	1.15	4.31	1.67		
50	1.11	3.93	2.37		
51	1.11	3.24	1.17		
52	1.25	3.55	2.13		
53					

	1	2	3	4	5
54					
55	MEAN DEPTH	MEAN VEL 6/10	MEAN VEL NOSE		
56	1.233333333	3.56461538462	1.77641025641		
57	0.278533125	0.67730054805	0.512093161649		
58	1.42	2.6	1.67		
59	1.62	2.1	1.25		
60	2	2.23	1.51		
61	1.75	2.15	1.17		
62	1.4	2.23	2		
63	1.6	1.72	1.55		
64	1.65	1.51	1.27		
65	1.76	1.37	1.02		
66	1.2	2.48	2.01		
67	1.2	2.48	2.01		
68	2.22	2.43	1.21		
69	1.8	2.75	1.75		
70	1.28	2.15	1.78		
71	1.5	2.08	1.93		
72	1.78	1.73	0.78		
73	1.75	1.82	1.2		
74	1.42	2.04	1.79		
75	1.64	1.46	1.09		
76	1.2	1.6	1.45		
77	1.58	2.6	1.7		
78	MEAN DEPTH	MEAN VEL 6/10	MEAN VEL NOSE		
79	1.5885	2.0765	1.507		
80	0.270170998	0.41372855327	0.367668328796		
81					
82					
83	0.42	2.85	2.32		
84	0.55	2.46	1.65		
85	0.89	3.43	2.41		
86	0.98	2.95	2.1		
87	0.54	3.48	2.5		
88	0.58	3.7	2.57		
89	0.97	3.8	1.64		
90	0.52	3.37	1.81		
91	0.81	2.38	1.77		
92	0.62	2.68	2.1		
93	0.55	2.93	2.27		
94	0.68	2.82	2.2		
95	0.71	2.84	2.06		
96	0.95	3.63	2.07		
97	0.95	2.99	1.65		
98					
99	MEAN DEPTH	MEAN VEL 6/10	MEAN NOSE VEL		
100	0.714666667	3.08733333333	2.07466666667		
101	0.193459729	0.4496898402	0.312452663081		
102					
103					
104					
105					
106					

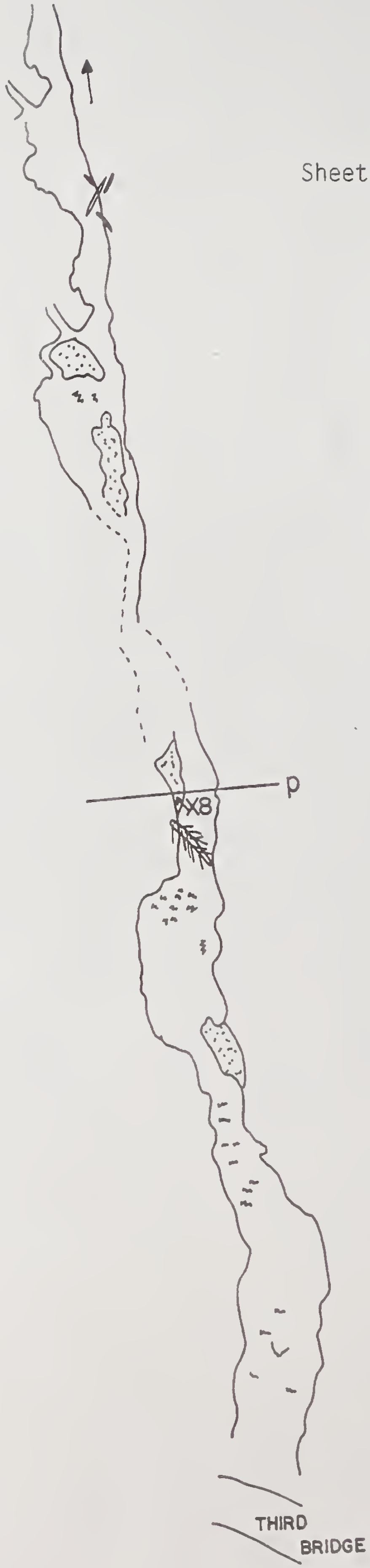
- APPENDIX D -

Map of West Fork of Hyalite Creek from No. 3 Bridge
to Window Rock Bridge

HYALITE CREEK BETWEEN WINDOW ROCK BRIDGE AND THIRD BRIDGE

—	DEPTH/VELOCITY TRANSECTS
X	IDENTIFIED SUITABLE SPAWNING SITES
●	POTENTIAL SPAWNING SITES IDENTIFIED ON VIDEO TAPE
	GRAVEL BARS
	LOG JAMS, TREES
	RIFFLES
	FLOW DIRECTION

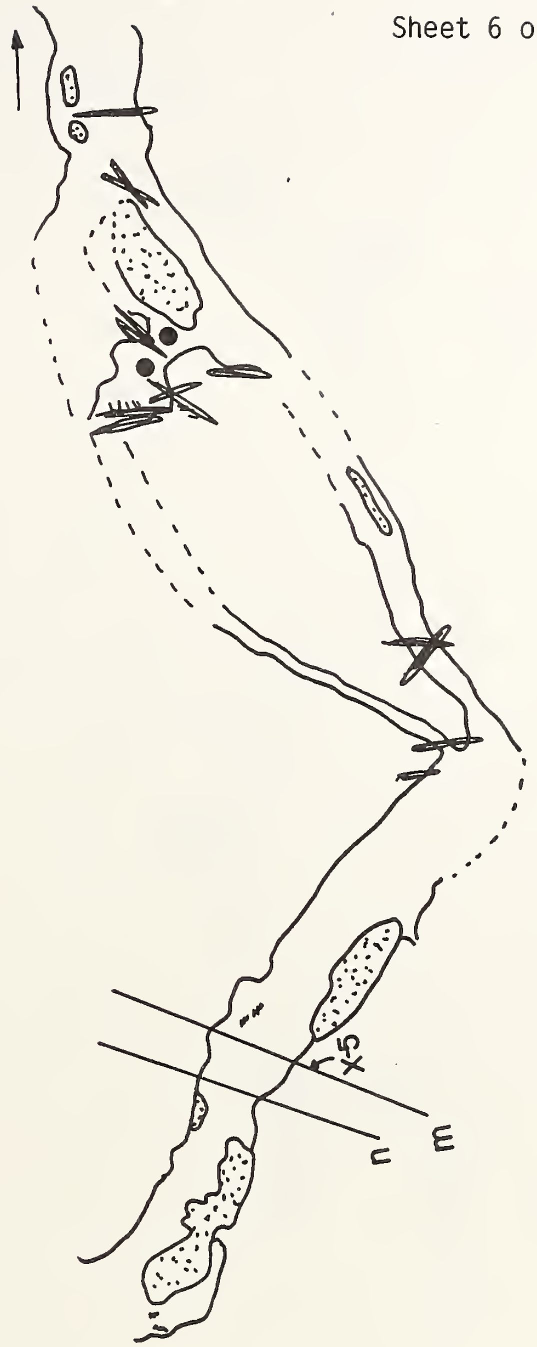
NOTE: DASHED LINES WHERE STREAM BANKS WERE NOT VISABLE ON VIDEO TAPE



P
X8
THIRD
BRIDGE


O


X-6



Sheet 7 of 7